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# Devolpment and Modeling Of an Industrial Process Plan, Its Optimization using stochastic search Optimization Technique

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***Abstract*—Industrial process planning is principally an association between design and development or final production and has vital function in the manufacturing systems. In this paper the under research industry is security vehicle manufacturing industry in Pakistan. First of all a fundamental process plan is developed and then modeled mathematically using progressive closed loop approach. Mathematically modeled process plan is then optimized in order to find optimal or sub optimal solutions. Research then investigates the capability of an innovative optimization technique called stochastic search in handling optimization of manufacturing process plan. This new technique of stochastic, searches the best approximate process planning solution. Finally the research examines the convergence of optimization techniques to an optimal solution for a manufacturing framework.**

**Keywords—*manufacturing process planning; stochastic search; optimization; manufacturing.***

## I. Introduction

Production processes are the production procedures where raw materials are changed into the premeditated products. These operational procedures ought to be resolute following complete manufacturing planning and completion of manufactured goods' design. This decision making is known as process planning. Every manufactured artifact has various planning connected by it. In manufacturing it is theoretically referred as process planning. The first job of the manufacturing workforce as they get novel drawings is to carry out the process planning [1]. This task, once finished, usually direct both the organization and the authentic manufacture of product. Process planning in manufacturing setup offers a specific and clear chronological path regarding how the product is to be routed and fabricated in a manufacturing. In highly developed manufacturing systems, this will persuade how the setup will be planned and laid out in preparation for the new product [2]. The case study product is the door and side plate of armored security transport vehicle (AST). Aluminum is used in the side plate for keeping the weight low. The AST manufacturing facility is very large scale manufacturing place, where armoued defense transportation carrier, armoued combating transporters are manufactured for security and law enforcing associations. In this paper, the section one is the introduction. Section two is regarding process plan modeling's parameter section and optimization. Section three deals with process work flow design. Section four focuses on the novel approach of stochastic search optimization. The section five is data modeling and finally is the deductions of the stochastic search approach.

## II. Process Parameters, Modeling and Optimization

The mode of production has changed with time in the following three ways. In old era, natural world was the only source of the affluence; farming, hunt, mining and their akin to be essential productive activities. Two hundred years back, pioneer of such as Adam Smith, David Richard and john stuart Mill theory of 'vendibility: production intended for market'. The name 'manufacture' initially appear in year 1622, stem from the word manu factum (atin / made with hand). Production is this logic put particular stress on manufacture the things by hand [4]. Then the time of industrialized revolution came and researchers start thinking on fast production methods in shortest possible time. The main three parameters; cost, time and quality were a big challenged to be optimized. All the production activities have one thing common as their back bone and it is the production process planning [1][3].

A process plan specify all unrefined supplies that are necessary to manufacture a meticulous result and how these raw materials would be transformed into a completed manufactured goods by application of a definite processes and operations. In a reconfigurable manufacturing system design, aim is to cope with the stochastic changes in the manufacturing environment through reconfiguration and offer time and cost effectual response [4]. Well-organized industrialized manufacturing activities, merger and synchronization of 3 flows those are critical. Firstly material flow (the transform of a raw materials into products) the secondly the information flow (planning & control of production) and thirdly the cost flow (economical production). To segregate theses flows, it is essential to break up the drawings into their divisions at this moment. Each part must have a clear tag so that it can be recognized. This phase necessitates a cautious study of each part and determining a variety of processes required to manufacture it into the form exposed in the drawing. The

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scheduled tasks are then sequenced so that they pursue the order in which they will be executed. The sequencing order is vital as the catalog just scheduled the recognized processes necessary to manufacture a part; however it did not organize in the order or sequence in which they will take place through the fabrication procedure. Instructions specify which terminal to route and which comes next, until the parts are accomplished. Because of the variety of engineering design problems, it is not possible to discuss the formulation of various optimization problems that are usually encountered in engineering design [5][6].

Different considerations often adopted in formulating engineering optimization problems. For a design problem to be optimized the first thing is modeling as foundation. A mathematical model of a system is an abstraction of the reality it is meant to portray. We can say when system variables, parameters, constraints and functional relations are described by symbols rather that physical devices, a mathematical model evolves. If the system's behavior could be studied continuously with the help of a model, then it is a Continuous Mathematical Model. If the changes in states are observed at regular intervals of time, then it is called a Discrete Mathematical Model. So by definition our model is discrete [7][8].

This research work spotlights an optimization approach which will optimize the processing time. There is no rigid principle to choose a priori parameters which may be important in a problem, because one parameter may be more important with respect to minimizing the overall cost of the design or the time of production, while it may be insignificant with respect to maximizing the life of the product. Thus, the choice of the important parameters in an optimization problem largely depends on the requirements of design and use. Thus, by selectively choosing the design variables, the efficacy of the optimization process can be increased. In the formulation of an optimization problem, rule is to choose as few design variables as possible. The outcome of that optimization procedure may indicate whether to include more design variables in a revised formulation or to replace some previously considered design variables with new design variables[9][10. A stochastic mathematical model is proposed in our research work, where symbols to represent variables instead of some physical entities. The stochastic models optimize process planning time and reduce the process activities to reach at optimal process model.

## III. PROCESS AND WORK FLOW DESIGN

Process planning involved in the AST side plate manufacturing is as fallow: In process cycle and work flow design, on the whole process routes from all stages that is the first stage of raw material till the final stage of product. The two processes planning stages that is the side plate and of side door runs in parallel and are done simultaneously. Work flow is analysed, all the stages are earmarked for a certain activity and the order is determined to translate unprocessed material into the complete product. Work stations are already fixed for each operation in the work flow. In this research paper, the Process routes from the first storage of raw material in the form of rectangular Aluminum plates. Now in the modeling as shown in the table- I below this storage is shown in the activity as "A". The second stage is Rough cutting. Then is the transport activity which is a non value added activity (other non value added activities are delay times, waiting times etc), so we cannot give it any notation (A to Z) but only the variable name is given and is X1. Since it is a controlled time, so we can add the similar transport times in this activity as shown in the table-I. In case of 8 X1, where eight different transport times are added having the same numeric value (in time / minutes). Al plates transferred to the savage saw for cutting .This rough cutting stage is denoted as activity "B" and the variable assigned is X2. The time consumed in this activity is 120 minutes is this is the uncontrolled time, since cutting is a operation. The plates are cut to size on savage saw and have become ready for installation on the (Computer Numeric controlled) CNC bench denoted by X6. Third stage is the Quality control QC-I which is a value added activity so it has both notation as well as the variable name. Similarly all the processes from B(X1) continue till assembly and final inspection BB (X40) are mentioned and modeled in the table – I below:-

Table I – Modeling of activities, variables and their times

| Ser No | Activity /Process (variable) | Activity Notation | Variable Name | Time in minute | Final variable set | Final variable Time |
|---|---|---|---|---|---|---|
| 1 | Storage | A | X | | X | |
| 2 | Transport from storage to Rough cutting | Non Valued activity (NVA) | X1 Transfer Time (T.T) | 15 | X1^=X10+X14+ X16+X18+X22 +X26D+ X27S =8X1 | 15+15+15+15+15 +15+15+15 = 120 |
| 3 | Rough cutting | B | X2 Operation time (O.T) | 120 | X2 | 120 |
| 4 | Delay from cutting to Quality Control (QC) | NVA | X3 Waiting time (W.T) | 10 | X3^=X3+ X31S+ X31D+X39 =4X3 | 10+10+10+10 = 40 |
| 5 | Quality control Inspection-1 | C | X4 Inspection Time(I.T) | 20 | X4 | 20 |
| 6 | Transport from Cutting stand to CNC machining | NVA | X5 (T.T) | 10 | X5 | 10 |
| 7 | CNC machining top side Phase-1 | (D for total activity) E | X6 (O.T) | 200 | X6 | 200 |
| 8 | Transport | NVA | X7 (T.T) | 20 | X7^=X29S+X7 +X36+X38= 4X7 | 20+20+20+20 = 80 |
| 9 | CNC machining bottom side Phase-2 | F | X8 (O.T) | 100 | X8 | 100 |
| 10 | QC-II | G | X9 (I.T) | 50 | X9 | 50 |
| 11 | Transport from CNC machine to drilling station | NVA | X10 (T.T) | 15 | X1^ | X1 |
| 12 | Semiautomatic drilling | H | X11 (O.T) | 120 | X10 | 120 |
| 13 | Delay time | NVA | X12 (W.T) | 20 | X11^=X12+X28 D= 2X11 | 20+20 =40 |
| 14 | QC-III | I | X13 (I.T) | 20 | X12 | 20 |
| 15 | Transport from drilling to hydraulic press | NVA | X14 (T.T) | 15 | X1^ | X1 |
| 16 | 400 tons Hydraulic press | J | X15 (O.T) | 30 | X13 | 30 |
| 17 | Transport from press to deberring | NVA | X16 (T.T) | 15 | X1^ | X1 |
| 18 | Deberring | K | X17 (O.T) | 30 | X14 | 30 |
| 19 | Transport from Deberring to Surface Treatment | NVA | X18 (T.T) | 15 | X1^ | X1 |
| 20 | Surface treatment phase-1 | L | X19 (O.T) | 50 | X15 | 50 |
| 21 | Delay time | NVA | X20 (W.T) | 30 | X16^=X20+X23 S+ X25S+ X24D+X33S+X 33D= 6X16 | 30+30+30+30+30 +30 = 180 |
| 22 | QC-IV | M | X21 (I.T) | 20 | X17 | 20 |
| 23 | Transport time from surface treatment to semi auto welding | NVA | X22 (T.T) | 15 | X1^ | X1 |
| 24S | Delay time | NVA | X23S (W.T) | 30 | X16^ | X16 |
| 25D | Steel plasma cutting | N | X23D (O.T) | 480 | X18 | 480 |
| 26D | Delay time | NVA | X24D (W.T) | 30 | X16^ | X16 |
| 27S | Semi automatic Welding side plate | R | X24S (O.T) | 230 | X19 | 230 |

Table I – Modeling of activities, variables and their times (cont…)

| Ser No | Activity /Process (variable) | Activity Notation | Variable Name | Time in minute | Final variable set | Final variable Time |
|---|---|---|---|---|---|---|
| 28D | QC-V | O | X25D (I.T) | 50 | X20 | 50 |
| 29S | Delay time | NVA | X25S (W.T) | 30 | X16^ | X16 |
| 30D | Transport time plasma cutting to semi automatic welding | NVA | X26D (T.T) | 15 | X1^ | X1 |
| 31S | QC-VII | S | X26S (I.T) | 30 | X21 | 30 |
| 32D | Semi automatic welding of Door | P | X27D (O.T) | 180 | X22 | 180 |
| 33S | Transport of side plate from welding to surface treatment | NVA | X27S (T.T) | 15 | X1^ | X1 |
| 34D | Delay time | NVA | X28D (W.T) | 20 | X12^ | X12 |
| 35S | Surface treatment side plate Phase-1 | T | X28S (O.T) | 50 | X23 | 50 |
| 36D | QC-VI | Q | X29D (I.T) | 20 | X24 | 20 |
| 37S | Transport of side plate from phase 1 to phase 2 of surface treatment | NVA | X29S (T.T) | 20 | X7^ | X7 |
| 38S | Surface treatment of side plate phase-2 | U | X30S (O.T) | 15 | X25 | 15 |
| 39D | Surface treatment of Side door and accessories | W | X30D (O.T) | 60 | X26 | 60 |
| 40S | Delay time | NVA | X31S (W.T) | 10 | X3^ | X3 |
| 41D | Delay time | NVA | X31D (W.T) | 10 | X3^ | X3 |
| 42S | QC-IX | X | X32S (I.T) | 30 | X27 | 30 |
| 43D | QC-VIII | V | X32D (I.T) | 30 | X28 | 30 |
| 44S | Delay time | NVA | X33S (W.T) | 30 | X16^ | X16 |
| 45D | Delay time | NVA | X33D (W.T) | 30 | X16^ | X16 |
| 46 | Assembly stage | Y | X34 (O.T) | 280 | X29 | 280 |
| 47 | QC-X | Z | X35 (I.T) | 30 | X30 | 30 |
| 48 | Transport from assembly stage to painting and drying station | NVA | X36 (T.T) | 20 | X7^ | X7 |
| 49 | Painting and drying | AA | X37 (O.T) | 480 | X31 | 480 |
| 50 | Transport from Painting stage to Quality assurance Department | NVA | X38 (T.T) | 20 | X7^ | X7 |
| 51 | Delay time | NVA | X39 (W.T) | 10 | X3^ | X3 |
| 52 | Quality assurance | BB | X40 (F.I.T) | 200 | X32 | 200 |
| | | | | | TOTAL TIME = | 3395 min =56.583 Hours= 7.07 =~ 7 working days |

## IV. STOCHASTIC SEARCH OPTIMIZATION

The meaning of a local, a global or an inflection point relics the identical as for single variable functions; but optimality criterion for multi-variable functions are dissimilar. We have carried out the modeling of process plan in the table –I mentioned above. Forty variables from X1 to X40 have been modeled. We model this process in the form of flow diagram as show in model 1 in Fig. 1 to show the relationships among various activities and the how the product routs in the complete procedure. The model 1 in the Fig. 1 shows all the activities as actual timings, as well as, the sequence of the activities in the way actually performed in the factory. The variable X are the activities time and the activities are shown in the form as of abbreviations like T.T as transport time, O.T as the operation time, D.T as the delay time and I.T as the quality inspection time. The combined or integral sum of Xs is abbreviated as activities Y. And all these process activities are integrated / summed to form the new activities shown as Y, shown in the model 1 and model 2 in Fig.1 and Fig.2 respectively. Subsequently Y1=X1+X2+X3+X4; and same for other integrations of Ys. So we can write in form of (1) as;-

$$Y(j) = \sum_{i=1}^{i=n} X(i) \qquad \begin{cases} i = 1,2,3\ldots\ldots.40 \\ j = 1,2\ldots\ldots\ldots\ldots.10 \end{cases} \qquad (1)$$

Before applying the integral Y, in the Fig. 2, Model 2 we further narrow down the time variables Xs from X40 to X32 by combining necessary non - value added time / activities that got similar in numeric value into the single activity such as 8X1 is the sum to eight transport time and so on.

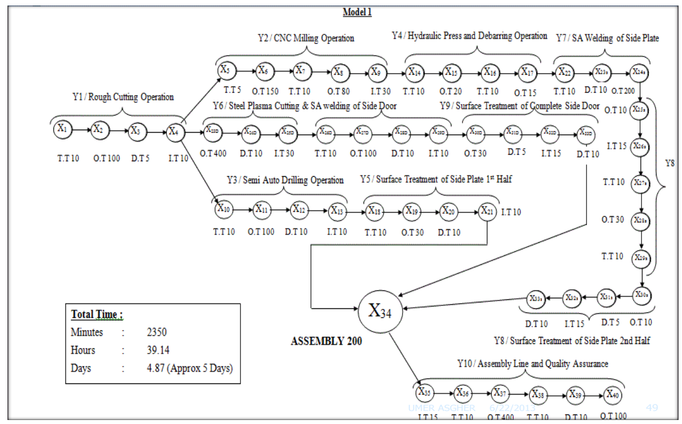


Fig. 1 Integral model stage I

On wards is the further simplification on the notations is done and Xs are grouped in integral variables Y for representation of the manufacturing process in terms of combined time(Y). Model 10 in Fig. 3 shows that Y1( R.T) is the rough cutting process and Y2 is the CNC machining process and so on till Y10 which is the assembly process. It means now we have represented the process as large activities (sum of individual activities) instead of individual ones.

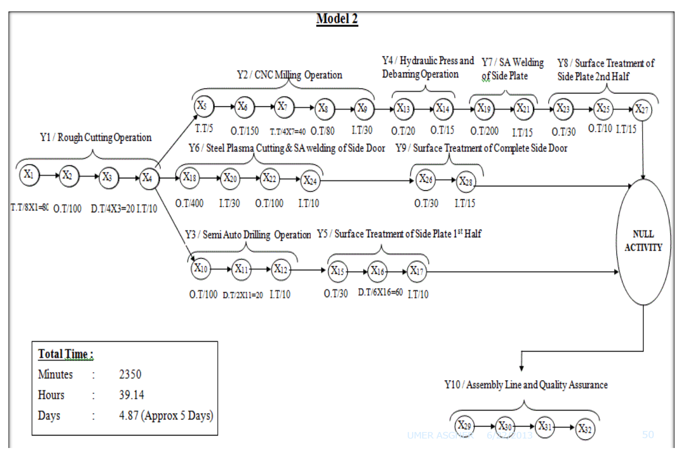


Fig. 2 Integral model stage II

From the model 10 and on wards we have further integrated the group activates to form large groups having more than one Y but with similar lines and facility locations. For example the integral activities of the side door are combined to form a single activity. The method we used to compute is a sort of non-linear or overlapped method which will converge to a stochastic Search optimization. It is stochastic time overlapping method to compute the results considering all the constraints.

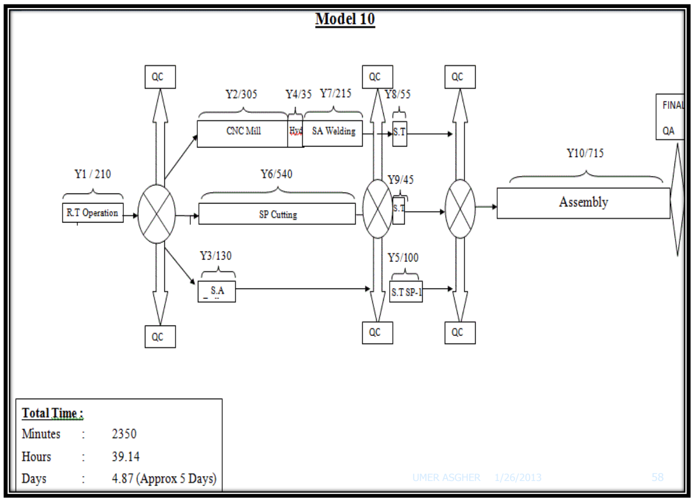


Fig. 3 Stochastic integral model stage III

The model 10 in Fig 3, we represent the transition of linear and non linear / overlapped activities. Y1 is the simple linear sum of activities because it doesn't contain time any overlap activity. Whereas the activities such as Y2+Y4+Y7, Y6 and Y3 are in parallel / overlapped in time, so we can combine them by double integration / summation and choosing the largest time (best time) after applying it to the all overlap group based on the stochastic search . In this case whole sum Y2+Y4+Y7 =555 > Y6=540 > Y=130. Here 555 are the largest and has the highest time span and all the other overlapping activities can be performed in parallel to that time, so stochastic algorithm pick this activity. Same is the case of the surface treatment activities of the side plate and the side door Y5=100>Y9>Y8=55.So the master activity here is the Y5 and all the other parallel activities will be performed in time overlap to that activity. At the end Y7 is the master activity as it's the simple sequential sum, so its values are considered as it is.

## V. DATA MODELING

As discussed earlier, in the model 10 in Fig. 3 we have deduced a new non linear double integral activity model, in which we have reduced the time activities Y from 10 to 4. These stochastic activities are denoted by Z and their values are not simple algebraic sum rather they are dependent on double integration / summation of the activities Y and choosing the best one activity having the largest time span. The relationship of the Z with Y is as fallow in (2):-

$$Z(j) = \sum \sum \sum_{i=0}^{i(x)} Y(i) \quad (2)$$

Where $i(x) = \begin{cases} j(x), & j = 1,10 \\ j(x*), & 10 > j > 1 \end{cases}$

Here we have introduced a new random variable i (x) whose value directly proportional random variable j(x) in case where the j has the values 1 or 10. It means the values of Z are the same summation sum of Xs or Ys. But the case where the time overlap occurs, there maximally large random variable (largest time span activity) having the maximum variance is possible is selected.

$Z(1) = 210$; $Z(2) = 555$; $Z(3) = 100$;

$Z(4) = 715$; $Z = \sum_{n=0}^{n=4} Z(n)$.Z = 1580 minutes (3)

If we convert in days than the total time comes out to be 3 days. In case of actual manufacturing time by simple adding Xs it came to be 7 days. The same thing is deducted from the tabulated form where all the redundant activities of Y make negligible contribution towards the overall calculation of the final manufacturing time. Here again the concept is the same of combining all the time overlap activities and selecting / stochastic searching the largest (best) while ignoring the activities which have the minor contribution and selecting the maximum span time activity.

Table II–Variable, actual time,Stochastic optimized time

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| X1,X2 ,X3,X4 | X5,X6, X7,X8, X9 | X10,X11, X12,X13 | X14,X15 ,X16,X17 | X18,X19 ,X20, X21 | X23D,X24D, X25D,X26D, X27D,X28D, X29 | X22,X23S, X24S | X25S,X26S, X27S,X28S, X29S,X30S, X31S,X32S, X33S | X30D,X31D X32D,X33D | X35,X35 X36,X37, X38,X39 X40 |
| 10+100+5+10 | 5+150+ 10+80+30 | 10+100+ 10+10 | 10+20+ 10 +15 | 10+30+ 10+10 | 400+10+30+ 10+100+10+ 10 | 10+10+200 | 10+15+10+30 +10+10+5+ 15+10 | 30+5+15+ 10 | 15+10+400+ 10+10+100 |
| Y1 | Y2 | Y3 | Y4 | Y5 | Y6 | Y7 | Y8 | Y9 | Y10 |
| 125 | 275 | 130 | 55 | 60 | 570 | 220 | 115 | 60 | 545 |
| X1,X2 ,X3,X4 | X5,X6, X7,X8, X9 | X10,X11, X12 | X13,X14 | X15 ,X16,X17 | X18,X20 X22,X24 | X19,X21 | X23,X25, X27 | X26,X28 | X29,X30, X31,X32 |
| 80+100+20+10 | 5+150+40+ 80+30 | 100+20+10 | 20+15 | 30+60+10 | 400+30+100 +10 | 200+15 | 30+10+15 | 30+15 | 200+15+400 +100 |
| Y1 | Y2 | Y3 | Y4 | Y5 | Y6 | Y7 | Y8 | Y9 | Y10 |
| 210 | 305 | 130 | 35 | 100 | 540 | 215 | 55 | 45 | 715 |
| Y1 | Y6,Y2,Y3 | Y5,Y9,Y4 | Y7 | Y8 | | | | | Y10 |
| Y1 | Y6,Y2,Y3,Y7,Y4 | Y5,Y8,Y9 | | | | | | | Y10 |
| Z1 | Z2 | Z3 | | | | | | | Z4 |
| 210 | 555 | 100 | | | | | | | 715 |

## VI. DEDUCTIONS FROM STOCHASTIC SEARCH OPTIMIZATION

We applied stochastic optimization techniques on process planning model / function and on all the constraints. The results obtained from stochastic Search optimization using time over lapped approach are quite impressive. Here it is obvious from the table II that there is a significant improvement in case the results from stochastic Search optimization and the optimization has dragged down the actual manufacturing time from 7 days to 3 days. The total time of manufacturing has decreased from 3570 minutes to optimized value of 1340 minutes. The percentage optimization achieved shows that stochastic Search optimization cover 53.46% of the total optimization area. So it clearly indicates that the stochastic Search optimization techniques achieve a near global optimum value.

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