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In-plant Material flow and storage analysis using discrete event simulation

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ABSTRACT: The paper presents an analysis of the materials flow in an automotive company for the effective and efficient material flow. The material flow planning team has empowered to take into account many aspects that have a significant impact on the internal transport of material during production. The analysis was carried out in three stages. The first step in the analysis was to determine the current situation of the flow of materials. In the second stage, the received data were used to develop a simulation model of internal transport, associated with the production, and the last stage of the analysis was to identify opportunities for rationalization actions. The rationalization concerned the optimum inventory level, required storage space, material traveling distance, and needed number of trolleys & bins for material storage and material replenishment.
Keywords: In-plant logistic, BIW shop, material flow planning, discrete event simulation.

I. LITERATURE REVIEW:

Literature shows research on logistics problems has attracted significant academic attention in the recent years. Previous studies indicate that the requirement for corporate sustainability has been recognized over two decades ago, although it has just in recent times increased its attention throughout the business world because of the growing taking competitive advantages. Nowadays, the organizations are becoming more competitive to minimizing their material handling cost.

OumerAbduaziz [1] Merrick & Bookbinder cite that transportation as the main source of risks in the logistics system. Therefore, reducing the vehicle kilometers travelled (VKT) is regarded as a reasonable technique to enhance organizational environmental practices. The amount VKT depends on the required distance between facilities and the number of trips required between nodes.

Nikhibakt [2] used genetic algorithm to minimize fuel consumption that collects and recycles automobile alternator at the end of their life cycle. According the author after adding a test function, the total fossil fuel consumption in the reveres logistic was minimized.

Pierreval [3] developed a model for automotive supply chain using system dynamics approach. The author considered the production units are at a macroscopic level. Dynamic behaviors of products flowing through logistic units were studied so as to better understand the global performance of the supply chain and how it reacts in particular circumstances.

Thom [4] conducted research on the development of empirical multitier studies capable of investigating the inter-organizational components concept of supply chain flexibility. This research has selected three representatives from the supply chain of the Brazilian automotive industry. The author highlighted that there is a lack of SCF empirical research in the literature analyzing concurrently the interrelations of multitier supply chains. However; this study did not show any numerical results indicating improvements within this topic.

[5] A case study was conducted on the sales and operations planning problem based on the actual situation of the Renault, a French global automobile manufacturer Laurent Lim. The flexibility rates are defined to limit orders of a given type of vehicles, during a certain period and the author developed a simulation model capturing the dynamics of the sales and operations management.

[6] OndřejKurkin and Michal Šimon contribution focuses on optimizing the layout of the two production lines for Daimler and VW Group products in the company BOS Automotive Products ltd. The main reason for this optimization is the reduction of the spatial arrangement of the production hall with regard to the planned production.

[7] Shigeki Umeda and Albert Jones paper proposes a system framework for supply chain management, which will form the foundation for the construction of an integration test-bed. This testbed will focus on production & operations management within the supply chain.

[8] J. Schmitt and M. Singh present a model constructed for a large consumer products company to assess their vulnerability to disruption risk and quantify its impact on customer service. Risk profiles for the locations and connections in the supply chain are developed using Monte Carlo simulation, and the flow of material and network interactions are modeled using discrete-event simulation.

The several analytical models for automotive logistics and supply chain discussed in the above paragraphs are based upon various reasonable assumptions which, when they hold, lead to important results. In this paper, simulation modelling is employed to incorporate a more general set of circumstances relating to in-plant logistics particularly the effect of material movement and optimal utilization of manpower and material handling equipment. These factors helps in optimizing inventory and cost involved in material handling.

II. INTRODUCTION:

Discrete event simulation has been widely used for the simulation of material flow and transport goods. The material flow costs can continue to be determined using software for the material flow analysis and allocated to other areas, processes, and departments. This analysis is therefore also used to save substantial time, resources, and costs. This analysis is also a fundamental aspect for the strategy and long-term planning of material process steps. The material flow planning is often performed using special software. We used Technomatix plant simulation application to build the simulation model. It allows to model, simulate, explore and optimize logistics systems and their processes. These models enable analysis of material flow, resource utilization and logistics for all levels of manufacturing planning, well in advance of production execution.

III. METHODOLOGY:

This work focused on relaying out material flow of a BIW shop assembly line, which is primarily responsible for the assembly of cab/cabin for heavy and medium commercial vehicles. The approach, to get effective and efficient material flow is building a simulation model that can be analyzed current scenario. Then examination step was completed by observed material movement distance, inventory level, number of resources and their utilization etc. After this, To-be scenario was developed that gave optimum outcomes. After that what-if analysis is done by changing required parameters to get best feasible scenario. For building simulation model, Technomatix Plant simulation application is used. This tool is based on discrete event simulation technique.

Scope, Objectives and challenges:

In-plant material flow refers material movement that happens only inside the plant. Basically from receiving centers to store followed by intermediate store or sub-assembly area then finally at line side where material is consumed or assembled with the product. In this terminology material movement from outside the plant or manufacturing unit is not considered. This study is done for a new upcoming BIW shop. There are four lines- Front wall line, sub-structure line, floor line and metal finish line. There are also three sub lines which are roof line, real wall and door lines.

The purpose of this analysis is to find out best possible root for supplying material from storage area to line side. And also determine optimum number of needed resources such as manpower, material handling equipment, trolleys and bins involved in material replenishment. Wastage involved in material flow should be minimum. Material flow is stream lined and cost effective. There is also a need to find out storage space so that needed inventory can be accommodate in store.

The challenges in the study were storage space which is available at two places store1 and store2 and inventory that need to keep in stores is high as comparted to a reference BIW shop and ensuring material flow should be streamlined.

IV. DATA COLLECTION:

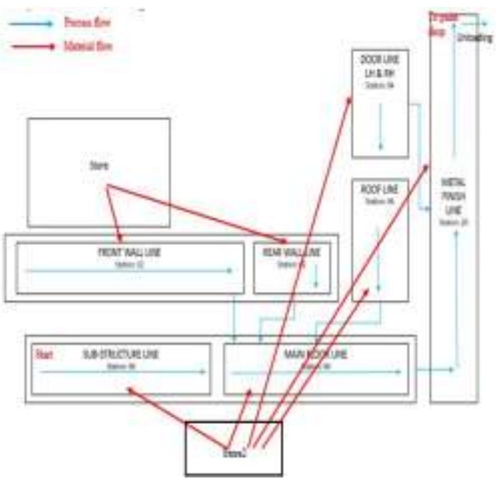
Data are the basic input to any decision making process in a business. The processing of data gives statistics of importance of the study. For this study both primary and secondary data were used. Primary data were material handling information, shift timings and process flow. Secondary data were shop layout, station wise or process wise part consumption list and assembly lines speeds. A general arrangement of departments, path ways, Assembly lines, store location, material loading and unloading points are represented in the shop layout. Material handling information collected from the observation method.It contains, trolleys or bins size and capacity information. Some other information collected were line availability and MTTR.

A. Part consumption list: Part consumption list contains part description, quantity, station number etc. All collected information has shown in below image-

[Table1-Part consumption list]

Line	Station	Part description	Validity	Assy. Type	Trolley Size (LxWxH)			Trolley capacity
Frontwall	FW10_1	Assy. panel outer W/S bottom	1	Part	2200	740	1700	28
		M8 nut	1	Bin part	530	300	300	500
		J clamp	2	Bin part	330	300	300	70
		Nut plate small	2	Bin part	530	200	200	76
	FW10_2	Nut plate	2	Bin part	330	300	200	70
	FW20	FW10_2	1	In-house SA	2200	740	1700	28
		Panel outer LH	1	Part	1850	900	1400	38
		Panel outer RH	1	Part	1850	900	1400	38
		Face panel LH	1	Part	1250	1200	1800	20
		Face panel RH	1	Part	1250	1200	1800	20
		Assy. Face support LH	1	Part	1750	840	1400	64
		Assy. Face support RH	1	Part	1750	840	1400	64
	FW20_1	Assy. Waist rail	1	Part	2150	690	1650	22
		Nut plate	2	Bin part	400	450	300	70
		J clamp	1	Bin part	400	450	300	70
	FW30	FW20_1	1	In-house SA	2150	660	1650	22
		ASSY DOOR POST LH	1	Part	1860	950	1100	24
		ASSY DOOR POST RH	1	Part	1860	950	1100	24

B. Block diagram of process flow: In the shop, material stored in store. It supplied to all assembly lines from stores in bins or trolleys. First flow starts from sub-structure line and continues to main floor line to metal finish line. The output of the front wall line, rear wall and Roof line assembled at main floor line and output of the Door line assembled at themetal finish line. In the shop, product flow has shown in below image.



[**Figure1-** Block diagram of the product and process flow]

Model building and validation:

Simulation model developed according to shop layout and validated its functionality that exhibit real behavior of the problem. Following steps were taken for building simulation model-

1. Shop layout import in the model
2. Material flow and information flow objects created in the model.
3. Writing of flow controls or process methods.
4. Model validated with reference to expected results.
5. What-if analysis performed to getting all possible outcomes from the system.

And after validation of simulation model, following results were generated-

1. Minimum and maximum inventory in store.
2. Needed inventory at line side to avoid material shortage.
3. Required number of trolleys and bins.
4. Congestion in the system.
5. Manpower required for material replenishment.
6. Needed space to store material.

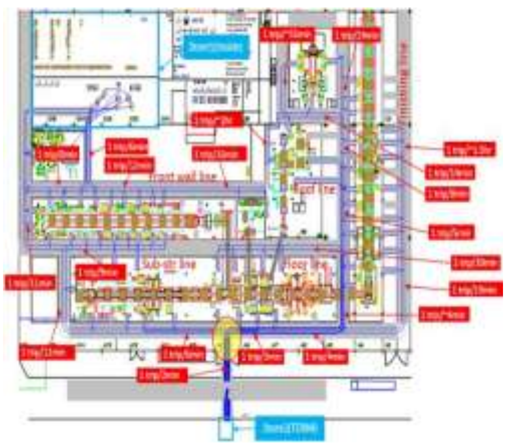
Current Scenarioresults and analysis:

The production happens in three shift a day and 6 days a week. Planned throughput was 200 cabs per day that validated with the model. Inventory that need to keep in store analyzed and varies from 1 shift to 2 days.Current scenario results is shown below-

Scenario	Inventory in Stores	Inventory at vendor end	Inventory in transit	Store	Available Area (Sqm.)	Total Occupied Area (Sqm)	Total number of trolleys	Total number of Bins
Current scenario	2 days	1 shift	6 hours (to & fro)	Store1	1019.46	1318.75	2178	1194
				Store2	1154.62	2089.98		

[Table2- current scenario results]

Space required to keep inventory is not sufficient. Available space is less than to the required space. Congestion in the shop identified and shown in below image.



[**Figure2**- traffic density and material flow- Current scenario]

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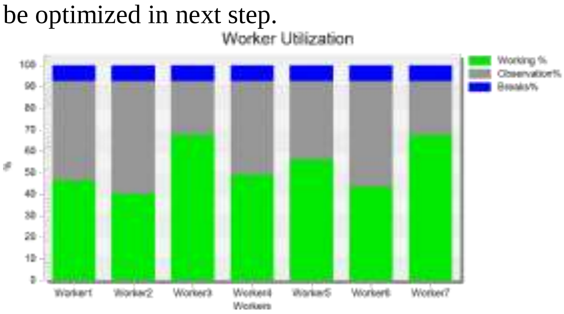
Most congested area identified in the shop and highlighted in above image. Traffic density at most congested area is 1 trip per 2 minutes.

Manpower required for material replenishment is determined. Material replenishment strategy was as follows. When one trolley gets empty at station, worker takes one filled trolley in store and replaced it with empty trolley. And when one bin gets empty at station, one filled bin loaded on a trolley and wait for other bin get empty when 10 bins loaded on trolleys then worker replaced empty bins with filled one by one at line side or stations.

[**Table3-** Manpower assignment matrix]

Worker Group	Line	Number of worker
Worker1	Front Wall Line	5
Worker2	Rear Wall Line	2
Worker3	Sub-Structure Line	4
Worker4	Roof Line	2
Worker5	Main Frame line	2
Worker6	Door Line	3
Worker7	Metal Finish Line	2

Manpower utilization is analyzed and shown in the graph. There is also scope for improvement in manpower utilization which will be optimized in next step.



[Figure3-Manpower utilization]

Improvements, Results and discussion:

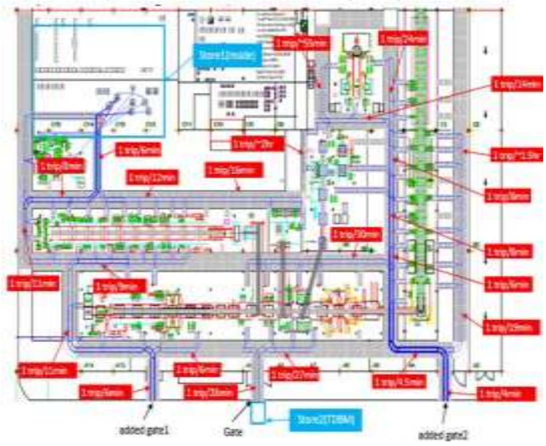
Following are the findings in current scenario that lead to inefficient material flow in the system.

1. Available storage space is not sufficient. Thus the inventory cannot be kept in store.
2. Congestion is high at the entrance of the shop for store2. It leads waiting in material replenishment and increase inventory at line side.
3. There is also scope to increase manpower utilization.

In next step, proposed scenarios developed in which above concerns that leads to material flow ineffective and inefficient, eliminated and developed more effective scenario by removing them in following ways.

a) Inventory that need to be kept in stores should be decreased and add additional space for material storage at the bottom side of the sub-structure line.
b) For de-congestion the system, 2 gates can be added and it decreased the material movement distance.
c) Manpower utilization can be improved by decreasing assigned manpower.

Congestion is a type of bottleneck. It leads wastage in the system. It increases delays in material replenishment and inventory which is in transit. It brought inefficiencies in the system that leads to higher production cost. So it is must require to de-congestion the system. It is removed from the system refer below image figure4.



[Figure4- traffic density and material flow-proposed scenario]

Congestion removed from the system by adding 2 gates as shown in above image. Now most congested area is identified at the entrance of added gate2 but it is acceptable as here traffic density was 1 trip per 4 minutes. Material traveling distance also reduced form 236 km per day to 169 km per day.

All experiments results shown in below matrix.

Scenario	Inventory in Stores	Inventory at vendor end	Inventory in transit	Store	Available Area (Sqm.)	Total Occupied Area (Sqm)	Total number of trolleys	Total number of Bins
Current scenario	2 days	1 shift	6 hours (to & fro)	Store1	1019.66	1118.35	2170	1193
				Store2	1154.62	2088.38		
Scenario2	3 days	1 shift	6 hours (to & fro)	Store1	1019.66	772.59	1615	985
				Store2	1154.62	1396.71		
Scenario3	1 days	Not considered	6 hours (to & fro)	Store1	1019.66	654.38	1049	572
				Store2	1154.62	1149.52		
Scenario4	2 shift	Not considered	6 hours (to & fro)	Store1	1019.66	522.11	569	299
				Store2	1154.62	1101.91		

[Table4- all scenarios' results matrix]

V. CONCLUSION:

Experiments results highlighted 2 factors that lead to keep high inventory. First, inventory at vendor end and second inventory in store. If only 2 shifts inventory kept in stores and do not store inventory at vendor end then minimum inventory can be achieved. It is validated with simulation model. There were also no material shortage at line side. It also leads to achieve needed storage space minimum that is 654 and 1149 square meter for store1 and store2 respectively. Minimum number of trolleys and bins required for material handling were identified as 569 and 299. Congestion level was also good after providing additional 2 gates for store2. Material movement distance was identified minimum which is 169 km per day. Optimum number of these parameter gives effective and efficient material flow in the shop. Surely cost involved in material handling will be minimum. Thus, proposed scenario4 is best feasible option for the material flow in the shop. These points were recommended to the management and the same scenario was implemented in the shop and found okay in running stage of the shop. Discrete event simulation tool is great help in analyzing and developing such simulation model.

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