Application of Discrete Event Simulation in Industrial Sectors: A Case Study

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***Abstract*— *Discrete Event Simulation (DES) has become a useful tool in the evaluation of changes that may bring positivity to manufacturing and process organizations for both goods and services provision. The main focus of any business entails the reduction of cost and lead time while increasing profits and this is why refining of production processes is essential. This paper reports the application of DES in two case studies. The case studies selected for the implementation of Discrete Event Simulation are a packaging company and a local mobile phone service provider using the software FlexSim. The implementation aims at showcasing the versatility and its ability to provide the relevant data to make more informed decision while optimizing the entire processes involved in production.*

Keywords — Implementation, Discrete Event Simulation (DES), FlexSim, production processes.

I. INTRODUCTION

The emerging trend in the manufacturing industry, which moves towards globalization and decentralization of managerial decision making processes require instantaneous information exchange between different points in the development of goods and services [7]. This instantaneous information described can be obtained through the process of simulation modelling. The simulation of manufacturing process proves to extremely simplified and cost effective. It is also capable of providing the user with past, present and future data (forecasting).

Simulation techniques have over time proved to be powerful tools for evaluating different processes in key areas of research and development. [5] argues that there are two approaches to simulation modelling, system dynamics and discrete event simulation (DES). The system dynamic approach to simulation aims at modelling processes that are continuous in nature. This type of simulation is mainly used in areas of fluid mechanics, thermodynamics among other engineering scenarios. The application of system dynamics is not limited to engineering applications, as use as been found in the area of economics, ecological systems, population modelling among others. The second approach discrete event simulation treats systems as a network of queues and activities whereby there is a change of state of the entity at discrete points in time along the process line. DES has been applied extensively in the area of operation management and manufacturing.

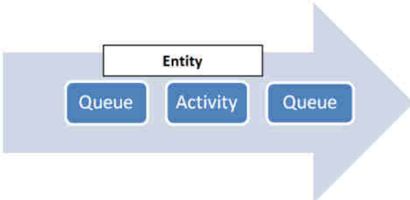

Fig.1: Schematic representation of the DES process

DES works with the rule that an entity must pass through a series of activities and in between an entity and an activity, a queue exists where the entity waits until it is ready to be processed. Fig 1 represents the DES process.

In the manufacturing industry, DES by virtue of its characteristics has been applied in different areas along product development including; inventory, production floor and supply chain management. Fig 2 below shows areas in the manufacturing industry simulation can be applied for investigation purposes.

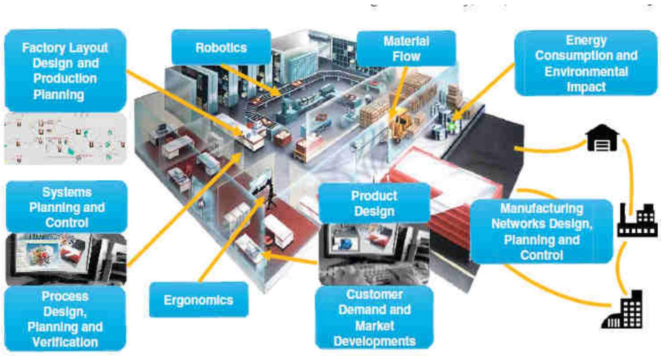

Fig.2: The investigated domains of contemporary manufacturing

Source; [7]

Discrete event simulation (DES) as a method of simulation has been present since the 1960s and overtime, it has evolved progressively for wider industrial applications. [1] states that till date, there have been four generations of software products being used for DES. This evolution has been from the use of programming in high level languages to interactive computer aided software. The generation of DES software are outlined below in table 1;

Table.1: Generations of DES software

1st Generation	Late 1960s	DES was done using high level languages such as FOTRAN
2nd Generation	1970s	The languages used for simulation where compiled to have commands such as statistical distribution generating, reporting etc. The model using the described simulation language was compiled to produce an executable model. Simulation packages produced in this generation include GPSS and AutoMod
3rd Generation	Early 1980s	The simulation languages were generated using 'simulation language generators'. They had the advantage of reduced time for model development compared to the 1st and 2nd generation DES software. Examples include SIMAN and EXPRESS
4th Generation	Late 1980s	This generation of DES software introduced 'interactive simulation' which had the capacity for simulation models to be modified anytime. Overtime, there have been upgrades to simulation software to include superior modelling and graphic capabilities. Example of these software include FlexSim, Arena and WITNESS.

Source: [1]

FlexSim is a 3-D DES computer software utilized for the simulation, validation, prediction and the visualization of systems in industrial sectors such as manufacturing, healthcare, logistics and material handling among others. The described computer software has the capabilities of optimizing a planned and already existing process for the purpose of lean production, reduction of production cost, increasing revenue and productivity.

II. LITERATURE REVIEW

Several works have been carried out over the years whereby DES has been applied to several other industries for the purpose of increase in productivity, cost reduction, issues of health care among others. For the purpose of this work, two sources of literature will be reviewed. These sources of literature will be reviewed in terms of the description, methodologies collection and interpretation process/results obtained.

A research with the title 'Validating the Existing Solar Cell Manufacturing Plant Layout and Pro-posing an Alternative Layout Using Simulation' was carried out to obtain the best layout in order to optimize the use of resources in terms of operators and machines. This optimization aimed at the reduction of production costs while increasing productivity. The case study chosen for this work was a solar photovoltaic (PV) module manufacturing company located in southern India. In order to achieve the set out aims, the DES tool ARENA© was used to 'examine the key performance variables' by using DES to obtain the best layout of operators and equipment. [2]

The objectives chosen for this works were;

I. Using simulation to validate the existing plant layout
II. Simulating the manufacturing process in order to identify bottleneck activities and proffer the optimal solutions.

In order to achieve the set aim, [2] set out steps that were followed sequencially. These steps were, model development, model verification and model validation.

In the model development step, the factory's current layout was studied and the process times and probability distribution of these 'process times' were evaluated. Assumptions were made in the development of the DES model. According to [2], these assumptions are;

I. Operators are always available during the two shifts (1 shift =8 hours), an hour of lunch break and fifteen minute of tea breaks will be provided.
II. There are no significant equipment or station failures.
III. The production is continuous.
IV. Processes for 60 cells and 72 cell modules have independent process time in pre-lamination stage.
V. Materials are always available at each assembly station.
VI. Transfer times between stations are taken as constant values

Furthermore, [2] explains that in data acqusition, four modules were required to supply all the data required to perform the simulation. These modules are;

I. Capacity Input: Information provided are the number of machines in each process and the schedule cycle of workers to operate.
II. Product specific data: All the data required for processing each product in terms of time, production rate and batch size.
III. User specific data: The modeller can customize the simulation by changing certain requirements as needed in the model.
IV. Scheduling production plan data: This provided data for the time taken by the plant to complete a demand.

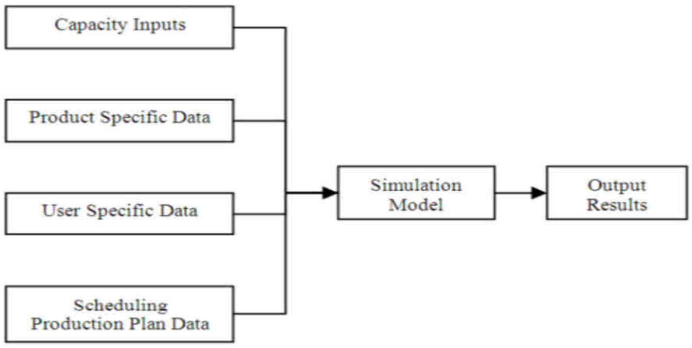

Fig.3: Simulation Model data flow

Source [2]

Model verification, the next step in the simulation process was conducted to make sure that the model worked as it was intended to. This step was described as an iterative activity performed at each step along the model development stage.
Model validation describes the demonstration to confirm that the model developed is able to describe the system it was modelled after. [2] split this process into two stages. The face validation and statistical validation.
The simulation was run for 400 hours during which the results represented in table 2 were obtained;

Table.2: Results obtained after simulation run of 400 hours

Number of hour's simulated	400
System throughput	5483
Work in process	469
Average resource utilization	50.58%
% Reduction in idle cost	60.0%

Sources; [2]
From the simulation, it was established that there was a bottleneck in the lamination stage and the assembly station consumed a large amount of time.
Based on the recommendations made by [2] with the objective optmizing the average resource utlization, work in process, system through put and % reduction in idle cost. The results obtained after the simulation with the recommendations are shown in table 3 below,

Table.3: Results obtained after optimization

	Results Before optimization	Results aft
Simulation time		**400 hours**
System throughput	5483	7093
Work in process	467	43
Average resource utilization	50.58%	73.40%
% reduction in idle cost	60.00%	25%

Sources; [2]
[3] describes 'end of monthe syndrome' in manufacturing settings as a situation whereby manufacturers experience difficulties in achieving their full potential If products exceeds 25% of the set monthly shipment plan in the last week of the month or more than 33% of their quarterly shipment plan in the last month of the quarter. This gave rise to the research titled 'Modelling and Simulation of Manufacturing Process to Analyse End of Month Syndrome'. The case study chosen is into the manufacture of two wheeler parts and special purpose machines. It is a tier 1 supplier to the seven customers which include; Honda, Ducati, Bajaj, Piaggio, Yamaha, Motorai Miner, Motto Guzzi. According to Kulkarni & Prashanth, discussions with the production heads of the company showed that it was overloaded with orders making it difficult for these orders to be fulfilled promptly, hence the end of the month syndrome.
The aim of the work as described by [3] was to suggest alternatives in overcoming the experienced end of the month syndrome after thorough analysis of the exsiting processes using modelling techinques. The objectives of undertaking the researcher were

I. Modelling and Simulation of manufacturing line to analyse end of the month syndrome
II. Reduce bottlenecks.
III. Prevent underutilization of resources
IV. Optimize system performance
V. Inclusion of new orders/customers
VI. Capacity improvement

The DES carried out by [3] was done using ARENA©. Based on the data collected during the discussion with the prodeuction heads, it was deduced that the 'end of the month syndrome' was caused in the Yamaha gear shifter manufacturing line (YMG Line). Further study by [3] reviewed that the contributing stages to the end of the month syndrome in the YMG line were rough honing, radius milling, pin machining, bending and pad grinding.
The data collected which was used in the simulation modelling are;

I. Machine wise data: The data under this category includes; number of machines, standard cycle time, manpower, start up loss, end up loss, target output, achieved output/shift, setting time, rework and rejection.
II. Machine cycle time
III. Dispatch plan
IV. Delay timing in the processing line.

Based on the data obtained, a virtual model of the process was built and fine-tuned until an 'As-is' condition was achieved [3]. 15 days of production runs for the YMG-7 and YMG-8 was simulated and results as described in table 4 below were obtained;

Table.4: Results obtained

ELEMENTS	AS-IS	AS-IS 50% DOWN TIME REDUCTION	AS-IS 75% DOWN TIME REDUCTION	RM CAP INCREASED to 2 SHIFTS	RM CAP INCREASED to 2 SHIFTS & 50% DT REDUCTION	RM CAP INCREASE D 3 SHIFTS
1.Number Out	42123	44054	44691	73332	74192	86474
2.Average Wait Time	Ymg 7 108.75, Ymg 8 108.36	Ymg 7 108.20, Ymg 8 107.90	Ymg 7 104.74, Ymg 8 104.40	Ymg 7 56.88, Ymg 8 56.77	Ymg 7 57.19, Ymg 8 57.62	Ymg 7 38.59, Ymg 8 38.58
3.WIP	Ymg 7 19610.35, Ymg 8 13083.54	Ymg 7 19346.77, Ymg 8 12858.85	Ymg 7 18897.01, Ymg 8 12572.09	Ymg 7 10278.48, Ymg 8 6783.32	Ymg 7 10326.55 Ymg 8 6900.32	Ymg 7 6878.14 Ymg 8 4555.14
4.Waiting Time	108.18hr	107.95hr	104.52hr	56.34hr	57.20hr	37.95hr
5.Number Waiting	32632	32179	31447	16948	17175	11271
6.Instantaneous Utiliza-tion	0.8169	0.8533	0.8651	0.8568	0.8603	0.8380

Source; [3]

Based the results obtained by [3] from the simulation model, it was shown that the bottleneck was the radius-milling machine. They recommended that '*by increasing radius milling machine capacity to 2 shifts and 50% of down time reduction on delay time in the line results into achieving the production schedule target on date thus reducing the effects of end of month syndrome substantially*'.

III. CASE STUDY IMPLEMENTATION

As described in the abstract, the DES tool was implemented in to scenarios using the FlexSim 3D simulation software. These case studies are described below;

3.1. Case study 1; Simulation of a customer service center in a mobile phone store

A customer service centre of a local mobile phone company has customers arriving exponentially with an average of 5 minutes. After entering the company, all customers go directly to the ticket machine to take an ordered ticket. They take 1±0.5 minute uniformly to do so. Then they go to the waiting area and sit down. The customers are waiting to request 1 of 3 representatives. Historical data shows that 40% of the customers want to see the representative of Network Service, 40% want to see the representative of Repair Service, and 20% want to see the representative of Billing Service. When the desired representative is available, a staff will escort the customer from the waiting area to the representative. When seeing the representative of Network Service, the visit lasts to be normally distributed with a mean of 7 minutes and a standard deviation of 2 minutes. When seeing the representative of Repair Service, the visit takes to be normally distributed with a mean of 10 minutes and a standard deviation of 2 minutes. The visit of representative of Billing Service lasts to be normally distributed with a mean of 5 and a standard deviation of 1. Some of the customers also see the Promotion Service after they have finished their servicing with the representatives of Network Service, Repair Service or Billing Service. An Assistant Manager will escort such customers to his room and introduces the promotion package individually. The introduction takes to be normally distributed with a mean of 10 minutes and a standard deviation of 3 minutes. Marketing Department found that 10% of the customers that enquire Network Service listen to the introduction of Promotion Service, 20% that see the Repair Service listen to the introduction of Promotion Service, and 5% who have seen the representative of Billing Service listen to the introduction of Promotion Service. After listening to the introduction of promotion with the Assistant Manager, the customers leave.

The resources employed in the simulation any model using FlexSim are categorised into fixed resources and task executers. Fixed resources as the name suggest are referred to as those resources which are stationery while task executors are used to perform the functions of moving items to and from the point of production. Table 5 and Table 6 below represent these resources;

Table.5: Fixed resources in Case study 1

Fixed Resources	Item
Source	Entry
Queue	Waiting Area Promotions Queue
Processor	Ticket Machine Network service Rep Repair service Rep Billing Service Rep Promotions Service
Sink	Exit

Table.6: Task executers in Case study 1

Task Executers	Items
Operators	Staff Assistant manager

The completed representation of the defined problem described in case study 1 is shown in figure 4.

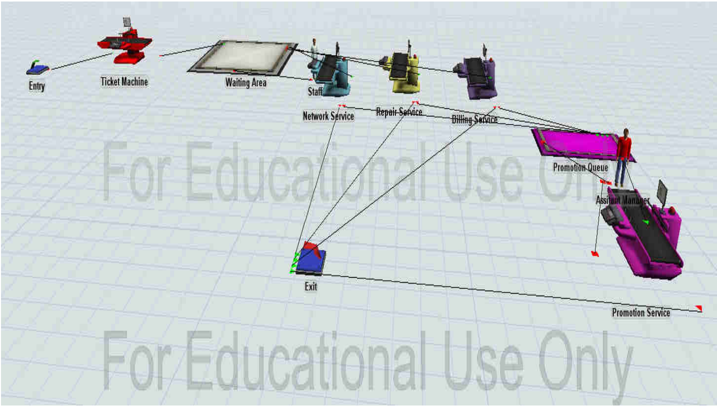

Fig.4: Completed FlexSim model Case study 1

3.2. Case study 2; Simulation of a tin can production company

A tin can arrives a Queue every 14 seconds exponentially distributed and then routed to any one of 3 machines where it is processed for 20 seconds (24 seconds for rework). Machined parts are placed in a common queue and wait to be tested, 20% are found faulty and must be reprocessed. The test time is a constant 9 seconds. Parts passing test enter another Queue and wait to be packaged at an automatic packaging machine.

The packaging machine accumulates 10 products into a box and then closes, seals, and labels the box in 57 seconds. The supply of boxes comes from a Queue fed by a box forming machine having a cycle time of normal (50,2) seconds. The box former jams regularly per

Weibull (151.1,50,24.9) and takes between 20 and 30 seconds to fix uniformly distributed. The Tester has an output of 80% acceptable and 20% faulty by chance. As performed in Case study 1 the fixed resources and task executers were defined as shown in tables 7 and 8.

Table.7 Fixed resources for Case study 2

Fixed Resources	Items
Source	Product source Box source
Queue	Product queue Test queue QC pass Box queue Final queue
Processors	Machine 1 Machine 2 Machine 3 Testing machine Box making mc
Conveyor	C1,C2,C3, C4, C5,C6, C7
Combiner	Packaging machine
Rack	Rack 1

Table.8 Task executers for Case study 2

Task Executers	Items
Operator	Operator 1 Operator 2 Operator 3
transporter	Forklift

Figure 5 represents the model created based on the available case study.

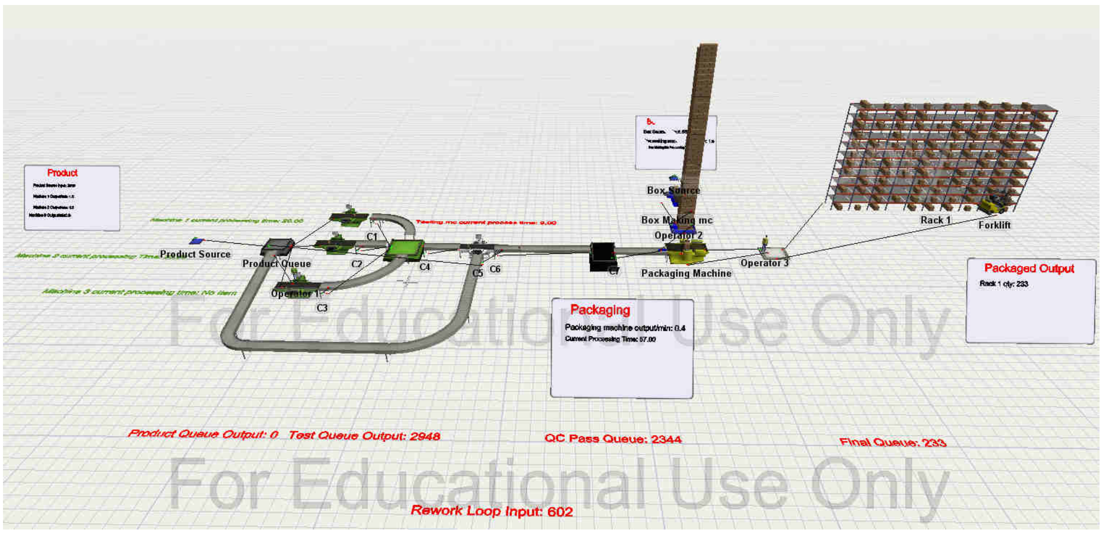

Fig.5: Completed FlexSim model Case study 2

IV. RESULTS AND DISCUSSION

4.1. Case study 1

The simulation model was run from 9:00am to 1:00pm (4 hours), which produced the results shown in tables 9 and 10.

Table.9: FlexSim summary report for case study 1

Model 1 Flexsim Summary Report
Time: 240 mins (4 hrs)

Object	Class	Min content	Max content	Average content	Input	Output	Min staytime	Max staytime	Average staytime	Idle Time	Processing Time	Utilize
Entry	Source	0	0	1	0	48	0	0	0	0	0	***
Ticket Machine	Processor	0	1	0.217445	48	48	0.534019	1.498651	1.069437	184.74	51.332969	***
Waiting Area	Queue	0	2	0.524749	48	48	0.094939	14.41732	2.614777	0	0	***
Network Service	Processor	0	1	0.613383	22	21	3.647012	10.94685	6.988186	92.498	146.751912	***
Repair Service	Processor	0	1	0.769305	18	18	7.103148	13.95456	10.20738	55.097	183.732904	***
Billing Service	Processor	0	1	0.264366	8	8	3.55118	6.541136	5.182521	115.37	41.460166	***
Staff	Operator	0	1	0.018596	48	48	0.070416	0.14176	0.092688	229.13	0	0
Promotion Queue	Queue	0	1	0.054149	9	8	0.040917	9.097539	1.616542	0	0	***
Assitant Manager	Operator	0	1	0.002046	8	8	0.058541	0.05877	0.058741	161.71	0	66.99825
Promotion Service	Processor	0	1	0.291684	8	7	5.615698	14.2888	9.571179	162.7	66.998254	***
Exit	Sink	1	1	0	45	0	0	0	0	0	0	***

Table.10: FlexSim state report for Case study 1

Flexsim State Report
Time: 240 mins (4 hrs)

Object	Class	Idle	Processing	Utilize
Entry	Source	0.00%	0.00%	0.00%
Ticket Machine	Processor	78.26%	21.74%	0.00%
Waiting Area	Queue	0.00%	0.00%	0.00%
Network Service	Processor	38.66%	61.34%	0.00%
Repair Service	Processor	23.07%	76.93%	0.00%
Billing Service	Processor	73.56%	26.44%	0.00%
Staff	Operator	95.77%	0.00%	0.00%
Promotion Queue	Queue	0.00%	0.00%	0.00%
Assitant Manager	Operator	70.40%	0.00%	29.17%
Promotion Service	Processor	70.83%	29.17%	0.00%
Exit	Sink	***	***	***

Based on the report generated in tables 9 and 10, the following observations were made;

I. The percentage of the staff's time spent in use as seen in the FlexSim state report is; (100%-idle time); (100%-95.77%) = 4.23%
II. The percentage of the assistant manager's time spent in use is; (100% - idle time); (100% - 70.40) = 29.60%
III. From the FlexSim state report the utilization of the 3 representatives are; Network service representative 61.34%, Repair service representative 76.93%, Billing service representative 26.44%.
IV. On the average, the waiting time for customers in the waiting area is 2.614777mins, 3mins approximately.
V. The most number of customers waiting to see the representative at one time as seen in the FlexSim report is 2 customers.

4.2. Case study 2

The simulation was run for 9 hours which represents the time for required for the completion of one shift. The results obtained as shown in table 11.

Table.11: Summary report for Case study 2.

Flexsim Summary Report	
Time:	32400 secs (9 hrs)

Object	Class	Current content	Average content	Input	Output	Average stay time (secs)	Idle time (secs)	Processing time (secs)	Total breakdown time (secs)
Product Source	Source	0	1	0	2350	0	0	0	
Product Queue	Queue	0	3.749717	2952	2952	41.14935	0	0	
Machine 1	Processor	1	0.631991	984	983	20.82197	11918.51601	20468	0
Machine 2	Processor	1	0.632616	984	983	20.84639	11900.47794	20492	0
Machine 3	Processor	0	0.630663	983	983	20.78128	11963.31274	20428	0
Box Queue	Queue	318	160.3389	552	234	9644.476	0	0	
Box Source	Source	0	1	0	553	48.45731	0	0	
Final Queue	Queue	0	0.076531	233	233	10.62024	0	0	
Box Making mc	Processor	1	0.999833	553	552	58.60646	5.388222	27576.71	3590.306539
Rack 1	Rack	233	113.0671	233	0	0	0	0	
Test Queue	Queue	0	0.000015	2948	2948	0.000167	0	0	
Testing Machine	Processor	1	0.818675	2948	2947	9	5874.465846	26523	0
QC pass	Queue	0	0	2344	2344	0	0	0	
Operator 1	Operator	1	0.334952	2952	2951	3.677002	10296.28167	0	0
Operator 2	Operator	0	0.039674	552	552	2.325681	29518.79609	0	0
Operator 3	Operator	0	0.03486	233	233	4.836418	30003.84176	0	0
Operator 4	Operator	0	0.03193	234	234	4.411625	30291.52461	0	0
Packaging Machine	Combiner	11	4.273628	2574	233	129.7494	2098.723213	13281	0
Forklift	Transporter	0	0.088024	233	233	12.2208	27026.56243	0	0

The reports obtained from the analysis of the data provided in the generated report shows that the total breakdown time for the packaging machine which was reported to be approximately one hour. This constitutes 11% of the total production time. The analysis further shows that the box making machine has the highest processing time of 7.6 hours.

V. CONCLUSION

DES has overtime proved to be an important method of solving a large variety of industry related problems spanning from production issues to managerial decision making processes. The concept of DES has found importance in other areas not limited to healthcare, inventory control, and supply chain management among others. As demonstrated in the sources of literature reviewed as well as the selected case studies, employing DES into the production processes will go a long way in not only identifying defective areas along the production process but also create an avenue to recommend solutions.

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