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APPLICATION OF AN INTEGRATED MODELING TOOL: UNITED PARCEL SERVICE

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ABSTRACT

Successful design and operation of modern production systems becomes more challenging than ever as they become more complex and more integrated. The time and effort involved in modeling these systems also becomes more demanding. Recently, a tool was developed to facilitate this process. This tool uses an integrated set of five software packages. These packages are: **LOTUS, MANUPLAN, SIMSTARTER, SIMAN,** and **CINEMA.** These five packages work as an integrated tool which takes a design idea from a rough cut stochastic analysis to a highly accurate real world simulation. In this paper, we present a case study on the successful application of this tool to a United Parcel Service Reload operation.

1 INTEGRATED SOFTWARE PACKAGES

Figure 1 below illustrates the interactions of the software packages in the system.

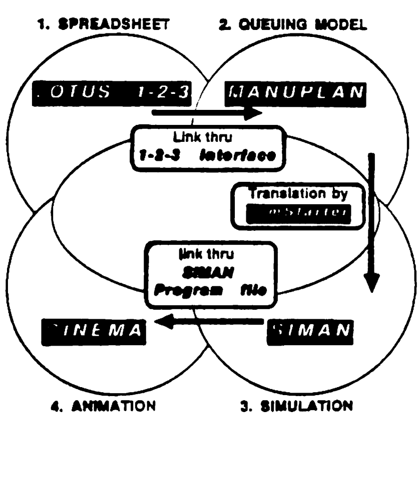

Figure 1: An integrated design tool for rapid modeling

1.1 Spreadsheet Analysis

The first piece of software is **LOTUS.** An example of a **LOTUS** spreadsheet is shown in figure 2 below. This spreadsheet package allows rapid data input for large "number crunching" computations. The package is very popular among many types of industrial businesses. The benefits in using **LOTUS** are the efficiency and simplicity of inputting data. By using **LOTUS**, the communication gap between accounting, management engineering, and all other departments in industry can be eliminated.

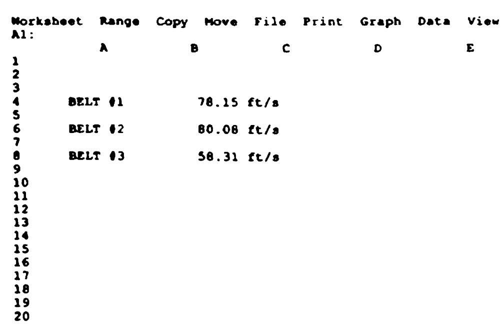

Figure 2: A Lotus spreadsheet

1.2 Manuplan Analysis

The next package in the sequence is **MANUPLAN.** This software uses **LOTUS** as an interface for inputting data. The **MANUPLAN** screen is used like the **LOTUS** spreadsheet. The menu choices are used to input different types of data into the **MANUPLAN** spreadsheet. **MANUPLAN** uses the **LOTUS** interface for rapid input of data. **MANUPLAN** is a rapid modeling technique which uses queuing and reliability theories and captures the dynamics and interactions of discrete manufacturing processes in terms of mathematical equations. **MANUPLAN** solves these equations in a minute or so and provides useful steady state performance of the system with reasonable accuracy. **MANUPLAN**, however, may not be appropriate for short-term decisions, nor for studying transient phenomena, nor when there is a significant amount of blocking in the system.

The data that is input into the spreadsheet interface consists of:

1. Model title and version information
2. Available time units
3. Utilization limit and variability
4. Equipment used in the system
5. Mean time to failure and time for repair
6. Part production information
7. Operation assignment for each part
8. Routing assignment for each part

After running **MANUPLAN** with the above input data, the following outputs are given:

1. Confirmation of whether production can be met
2. Total number of good pieces produced
3. Utilization of equipment
4. Percentage of capacity for setup, run, and repair
5. Scrap production for each part
6. Work in process
7. Total flow time through the system
8. Time spent at each piece of equipment

The detailed output from the United Parcel Service model can be observed in the application example in section 2.

1.3 Simstarter

After several iterations of **MANUPLAN**, the initial design parameters can be adjusted to levels which best represent the system under study. Having adjusted these parameters, **SIMSTARTER** is used to produce **SIMAN** code. This is the most time saving part of the sequence. Developing and verifying **SIMAN** code is a time consuming tedious process. It is possible for the analysis and simulation of complex systems to take several months. The code produced by **SIMSTARTER** may not completely define the system under study. It may be necessary to adjust the code to simulate blocking, starving, and material handling situations.

1.4 Siman Simulation

By using **SIMAN**, it is possible to evaluate the systems under real world conditions. Through the **SIMAN** source code, the user can represent conditions which **MANUPLAN** is unable to model.

1.5 Cinema Animation

Once the **SIMAN** code has been altered to simulate the process, **CINEMA** can be used to animate it. **CINEMA** is used to create a layout file using a CAD-like interface. In this layout file, a structure is created where entities, machines, and a background are placed. This layout file is driven by the **SIMAN** program file, and results in a working animation of the system.

CINEMA is an excellent communication medium between engineering and shop floor control. The shop floor supervisors can watch the process run and insight can be gained by observing part routings, queues, and blocking or starvation situations.

1.6 Observations

By using this integrated tool, a model can be created using a static spreadsheet model, enhanced using an analytical model, and perfected using computer simulation and animation. In order to fully demonstrate the functions and benefits of this model, an application example will follow. This example consists of a successful application of the tool to model and analyze the real world situation at United Parcel Service.

2 APPLICATION EXAMPLE: UNITED PARCEL SERVICE

This integrated model was applied to the Reload operation at a local United Parcel Service center. The objective of the study was to create a computer model that represents the real world operation at United Parcel Service. The model was then used to calculate the optimum operating conditions under varying demand. Variances in demand are a result of holidays, such as Christmas, and changes in the economy. The objective was accomplished by adjusting shift length (overtime) and manning. The system was subject to a constraint on work-in-process packages, due to conveyor belt capacities.

2.1 System Description

Before the modeling of the system is discussed, an overview of the system will be presented.

2.1.1 Processed Parts Description

There are five different types of parts processed in the system. These parts along with their method of arrival to the center are as follows:

1. **SMPKGS** - Small packages by package car
2. **BIGPKGS** - Large packages by package car
3. **MEDPKGS** - Medium packages by package car
4. **IRREGS** - Irregular packages by package car (Buckets, steel rods, etc.)
5. **CUSTPKGS** - Customer packages that arrive to the customer counter

2.1.2 System Equipment Description

In this system, there are six different types of equipment or workers. They are:

1. Two unloaders responsible for unloading all package cars
2. Three loaders responsible for loading the packages into outgoing trailers
3. A splitter responsible for routing the packages to the appropriate trailers (determined by zip codes)
4. Two small sorters; one responsible for sorting packages into the sort bin, and the other for bagging packages coming out of the bin
5. An irreg man responsible for sorting, carting, unloading, and loading irregular packages
6. A clerk responsible for accepting packages over the customer counter and inspecting damages

2.1.3 Package Flow

For the following package flow description, refer to the United Parcel Service layout (figure 3).

Packages enter into the system by package car. The trucks back to the dock where the unloaders remove all packages and place them on belt #1. If the unloader encounters an irregular package, he places it under belt #1 where it waits for 9 other irregs to accumulate. If the unloader encounters a small package, he places it in a tote box where it waits for 14 other small packages to accumulate. When 15 small packages are contained in one tote box, the tote box is placed on belt #1.

All regular packages that are placed on belt #1 are conveyed to belt #2 where they are sorted by the splitter. The splitter is located between loading docks 1 & 2. Once they reach the splitter, they are routed to one of five belts which lead to each loading dock. The routing once again depends on the zip code of the individual package. When they reach their destination, the loader loads them into the trailer.

Once 10 irregular packages have accumulated under the belt, the irreg man places them on belt #1. They are conveyed to the irreg area where the irreg man removes them from the belt and places them on the dock below. They wait here for the others to be pulled off of belt #1. Once the 10 irregs are removed from the belt, the irreg man sorts them by their zip code and loads them onto the appropriate cart. After all irregular packages have been processed in this manner, the irreg man pushes the carts to loading dock number 1 or 3. The irreg man removes them from the cart, places them on the loading dock and loads them into the trailer.

The small packages that have accumulated in the tote boxes are loaded onto belt #1 where they travel to the small sort bin. From here, the tote box is pulled from belt #1 and placed on the small sort bin stack table. The small sorter then "dumps" the tote and sorts the smalls

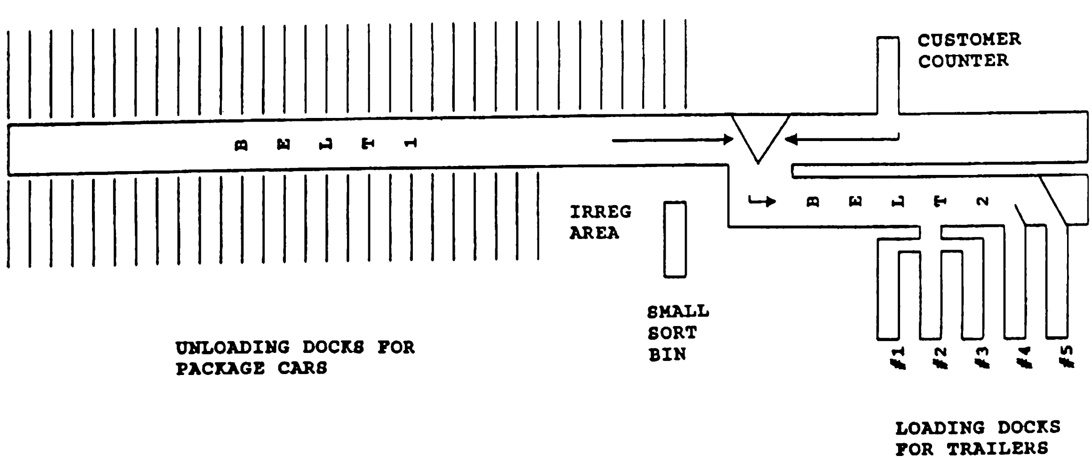

Figure 3: The United Parcel Service Facility

into the appropriate bin. The second small sorter places all of the smalls into small sort bags, tags the bag with a destination tag, and places the bag on belt #2. The bags travel to the splitter where he routes them the same as regular packages.

The customer packages are received by the clerk and placed on belt #2. They are conveyed to the splitter and routed the same as all other packages.

Damages are apt to occur on all packages placed on the belts. Although every precaution is made in order to avoid this situation, it still occurs. When a damage does occur, it is received by the splitter. The splitter removes the damaged package from the belt and routes it to the clerk for inspection. The clerk then inspects the package and decides if the contents are damaged. If they are not damaged, the package is placed on belt #2 where they continue as before. If the contents are damaged, the packaged is "scrapped" and a claim is paid to the customer for the damage done.

A blocking situation occurs occasionally between loading docks 4 and 5 when too many packages are waiting to be loaded into trailer 4 and/or 5. Because of the construction of the belt, if a block occurs, the only solution is to shut down belt #2 and clear the block. When belt #2 is shut down, belt #1 shuts down automatically. The splitter is responsible for clearing the block. Once the block is cleared, the belts are re-started, and production resumes.

2.1.4 Available Time

The Reload typically runs for 1.83 hours per day, 5 days per week, and approximately 250 days per year.

2.1.5 Present Part Production

The present production demand for each part is:

1. CUSTPKGS: 125
2. SMPKGS: 1100
3. MEDPKGS: 1350
4. BIGPKGS: 1350
5. IRREGS: 60

2.2 RELOAD SYSTEM ANALYSIS

2.2.1 Spreadsheet Analysis Using Lotus

The first step in the Reload analysis consisted of calculations involving minimum acceptable requirements (MAR's). The grounds for these calculations were based on data collected by time study teams at UPS. This data was entered into **LOTUS** to calculate time allowed per piece for each job. Timings were done on the belt velocities at UPS and this data was also entered into **LOTUS** to calculate the belt delays experienced by the packages in the system.

2.2.2 Queuing Analysis Using Manuplan

After the spreadsheet calculations were completed, the output data from **LOTUS** was used as input data to **MANUPLAN.** Workers were assigned to their individual tasks and part routings were then developed. In order to model the lot size changes for SMPKGS, the following delays were included:

1. A delay for accumulation of 15 packages in a tote
2. A delay for "dumping" the small packages
3. A delay for the time packages wait in the sort bin

For IRREGS, the following delays were included:

1. A delay for accumulating 10 irregs under belt #1
2. A delay for time spent waiting for the other irregs to be pulled off belt #1

MANUPLAN cannot model the buffer blocking situation between docks 4 and 5 that causes belt #2 to be shut down. Instead, we used the reliability feature in **MANUPLAN** to roughly model this blocking situation. A MTTF of 25 minutes and a MTTR of 1 minute were used for belt #2. In addition, the following were used:

1. 10% variability for arrivals and equipment
2. 95% utilization limit
3. Inspection on 2% of packages
4. Scrap rate of 1% on inspected packages

After running **MANUPLAN** under all of the above assumptions, the following results were obtained:

Table 1: Normal production output summary

EQUIPMENT UTILIZATION SUMMARY				TOTAL WORK-IN-PROCESS (in lots)			
EQUIP-MENT	% of capacity required for SETUP	for RUN	for REPAIR	Utili-zation	at EQUIP	in QUEUE	TOTAL
UNLOADE	.00000	89.937	.00000	89.937	1.7987	13.797	15.596
LOADER1	.00000	92.937	.00000	92.937	.92937	22.912	23.841
LOADER2	.00000	94.910	.00000	94.910	.94910	32.538	33.487
LOADER3	.00000	94.910	.00000	94.910	.94910	32.538	33.487
SPLITTER	.00000	92.131	.00000	92.131	.92131	20.146	21.067
SMSORTER	.00000	87.409	.00000	87.409	1.7482	3.7369	5.4850
IREGMAN	.00000	17.656	.00000	17.656	.17656	.02414	.20070
CLERK	.00000	32.097	.00000	32.097	.32097	.27200	.59297
STANDBY	.00000	.00000	.00000	.00000	5.7367	.00000	5.7367
CONV	.00000	.00000	3.8462	3.8462	65.708	4.7068	70.415

Desired production can be achieved				
PARTS	Good Prodn (pieces)	Scrap Prodn (pieces)	WORK IN PROCESS (pieces)	FLOW TIME dock-stok in HOURs
SMPKGS	1100.0	.00000	237.23	.39467
MEDPKGS	1350.0	.27551	92.725	.12569
BIGPKGS	1350.0	.27551	92.725	.12569
CUSTPKGS	125.00	.02551	6.6151	.09684
IRREGS	60.000	.00000	20.293	.61895
TOTAL PIECES:	449.59			

The output that was received from **MANUPLAN** was compared to the real world numbers obtained from United Parcel Service. The **MANUPLAN** results were extremely close to the real world situation.

The computer model developed, using the integrated tool, was very useful in addressing one of the frequently encountered planning problems, namely, finding minimal-cost planning for manning and workshift length during varying demand periods. For example, during the Christmas season, customer packages increase by more than 400%. Other packages also increase in different proportions: small packages by 100%, medium packages by 125%, and large packages by 50%. Using this seasonal demand as input, we applied the tool to find the minimal-cost combination of manning and workshift length. One constraint that must be taken into account is that the maximum number of work-in-process packages should not exceed 600, due to limited belt capacities. Using **MANUPLAN**, many possible combinations were evaluated and then narrowed down to the most cost effective solution.

In order to accommodate for the increase in demand, two factors were adjusted; shift length and workforce size. Because of the time constraints on outbound loads, the shift length should be kept as near as possible to the normal operating length. Manning however could be adjusted to accommodate for the demand increase.

After many iterations, the optimal solution for manning produced by **MANUPLAN** consisted of:

1. One additional splitter
2. Two additional unloaders
3. Two additional small sorters
4. Three additional loaders
5. An increase in shift length of .03 hours

The performance of the peak season system is summarized in table 2.

Table 2: Christmas production output summary

EQUIPMENT UTILIZATION SUMMARY				TOTAL WORK-IN-PROCESS (in lots)			
	% of capacity required						
EQUIPMENT	for SETUP	for RUN	for REPAIR	Utilization	at EQUIP	in QUEUE	TOTAL
UNLOADER	.00000	83.030	.00000	83.030	3.3212	5.8402	9.1614
LOADER1	.00000	90.893	.00000	90.893	1.8179	16.203	18.021
LOADER2	.00000	92.830	.00000	92.830	1.8566	21.262	23.118
LOADER3	.00000	92.830	.00000	92.830	1.8566	21.262	23.118
SPLITTER	.00000	90.111	.00000	90.111	1.8022	14.478	16.280
SMSORTER	.00000	85.084	.00000	85.084	3.4034	2.6473	6.0507
IREGMAN	.00000	17.186	.00000	17.186	.17186	.02275	.19461
CLERK	.00000	79.887	.00000	79.887	.79887	8.0853	8.8841
STANDBY	.00000	.00000	.00000	.00000	9.5032	.00000	9.5032
CONV	.00000	.00000	3.8462	3.8462	124.29	9.0418	133.33

Desired production can be achieved				
PARTS	Good Prodn (pieces)	Good Prodn (pieces)	WORK IN PROCESS (pieces)	FLOW TIME dock-stck in HOURs
SMPKGS	2200.0	.00000	332.42	.28406
MEDPKGS	3037.5	.61990	119.89	.074201
BIGPKGS	2025.0	.41327	79.924	.074201
CUSTPKGS	625.00	.12755	23.728	.071372
IRREGS	60.000	.00000	19.636	.61525
TOTAL PIECES: 575.59				

2.2.3 Detailed Siman Analysis

In order to perform an exact simulation of the Reload system, the simulation model needed to incorporate the following features:

1. Package car unloading based on the Prefered Order Rule
2. Routing of packages to their appropriate sorting station
3. Lot size changes for transporting small and irregular packages
4. A constraint on work-in-process packages due to conveyor belt capacities

From the source code produced by **SIMSTARTER**, changes were made to accomodate real world conditions that could not be modeled by **MANUPLAN.**

The first modification concerned the blocking problem experienced between loading dooors 4 and 5. The code was enhanced by assigning a random distribution to the MTTF of belt #2. When a failure occurs, the other workers in the system continue production. This results in starvation and blocking situations in the load and unload areas respectively. This modification allows for more accurate results concerning average utilization and queue length.

Lot size changes were modeled using specific **SIMAN** elements. These elements allow for grouping packages into specified lot sizes and splitting these lots easily when necessary. When grouped into lots, the packages in the system are considered as one entity. This is the best representation of the actual system.

Conveyor simulation was also accomplished using specific **SIMAN** elements. These elements consider belt spacing, length, and velocity. The interarrival times used within the simualtion are, therefore, more exact.

Outputs produced by the simulation include:

1. Flow times for each type of package
2. Utilization and number of packages in queue for each piece of equipment
3. Number of good and scrap pieces produced

2.2.4 Cinema Animation

The final step in the analysis sequence consisted of designing a layout similar to that of figure 3. Although the animation does not provide additional information about the Reload, its use as a communication medium was apparent. The package blocking situation, queue lengths, and package flow were all visible on the computer screen. The animation allowed the system to be viewed so that insight could be gained from visualization of the operation.

3 BENEFITS FROM USING THE INTEGRATED TOOL

Two major benefits were apparent from the United Parcel Service analysis.

3.1 Reduction In Model Building Time

There was an obvious reduction in the model development time. Table 3 below, shows the time spent using each software package.

Table 3: Summary of model building time

SOFTWARE PACKAGES	COMPUTER TIME MAN HOURS SPENT	PROCESSING TIME ZENITH 386 (hrs.)
1. LOTUS 123	2.0	0.02
2. MANUPLAN	7.0	0.50
3. SIMSTARTER	—	0.08
4. SIMAN	3.0	2.00
5. CINEMA	8.0	—
TOTALS	20.0 hrs.	2.6 hrs.

Because this was the first time using **MANUPLAN**, the time spent on that stage is believed to be longer than necessary. The most time reduction came in the simulation coding phase. Past experience shows that this phase can take months.

3.2 Planning Workforce Size and Shift Length

Results obtained from the Christmas peak demand period, showed that the computer model developed using the integrated tool can help to plan minimal-cost workforce size and shift length subject to the limited belt capacity for work-in-process packages. Such a planning problem frequently occurs due to demand fluctuations from seasonal and economic factors.

4 CONCLUSION

In this paper, we presented a case study on the application of the integrated tool on a package shipping facility of United Parcel Service. The tool enabled us to quickly develop a computer model which represents the facility very accurately. The tool was particularly useful in finding optimal planning (manning and overtime) under fluctuating seasonal and economic demand. Since this tool has a wide range of applications, it is apparent to the authors that the success experienced from this example extends to most industrial situations.

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