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Research Article

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Optimization of Packing in Steel Rack with Integer Programming to Improve Rack Filling Ratio

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Abstract In this globalization era all companies are trying to improve their competitiveness among others by optimizing their operational processes. This is made to increase their revenues and to reduce their costs. A logistics company engaged in export may optimize the space in the rack. The use of this rack is in line with the plan of space optimization in the container. In actual conditions, operators and the warehouse staffs use best practices in determining the items filled into the rack (puzzling), to decide what items to be filled into the rack. But of course it takes much time, especially when the items to be inserted in the rack are in large quantity and of various types. This study will use a software of decision support system (DSS) to calculate the optimization. The target of this study will be a proof that by using the software the job will be easier and better results compared to using best practice. After calculation we got the first optimized calculation result can be achieve 99.57% steel rack efficiency rating for 1st RV5 steel rack and 62.69% for RV5 steel rack type. The total number of RV5 reached 2.32 m^3 of the total space on the 2.33 m^3 steel rack. Although the total number of RV14 reaches 2 m^3 of the total space on the 3.19 m^3 steel rack.

Keywords Decision support system, Optimalization, Packing, Steel rack

1. Introduction

Shipment of export goods can be by sea or air transport. In shipment via sea transport, the goods are transported in containers or also called containerization. Cargoes that have been packed inside containers cannot be unloaded until they reach the destination port [18]. By using a container, it will save transportation costs and have more accessibility to other modes when required, such as land transport by trucks or trains. In addition, shipment in containers is considered safer and increases the company's margin by 10-20 percent [7].

Shipment in containers certainly cannot be made without a good layout planning, then packing will be the most important in determining layout planning and also determine the amount of containers to be used. Company A in this case uses returnable steel racks which is a standard for multi-national (global) companies in Japan. The retunable steel racks are rectangular in various sizes. This study is concerning packing automotive parts of various sizes of carton, plastic and other packaging types into the racks. To optimize the space and utilization of container, the optimization of rack filling ratio must first be optimized.

A good rack filling ratio shall be 80% of rack's loading space. Parts that come from the supplier have been packed in carton boxes and then arranged in the steel racks that later to be loaded into the container. An automotive company has standardized carton and rack size to make good filling ratio inside the container; however, it is still not optimal. The annual measurement in early 2017 showed that a 40 ft HQ container was loaded 53.9 cubic meters. As a reference, the maximum cubicity of a 40 ft HQ is 72 cubic meters. The annual measurements found that the loading is far from the management target. To improve efficiency, a study is made on packing optimization.

Currently, efficiency improvement is made by manual re-puzzling and it takes almost 1 month plus some stages of continuous improvement. This study will use 2 software applications, namely, QM for Windows and Cubemaster. QM software will be used to get the optimization and Cubemaster will be used to have visual simulation. This is known as good software in calculating packing optimization in container.

2. Material and Methods

2.1. Material

Having an integrated logistics management plan becomes a necessity at this time. Logistic management is a key issue today, capturing the essence of integrated logistics planning and management of activities involved internally and externally [15]. Logistics management planning makes exporters are encouraged to provide quality services to their customers while minimizing operational costs and maintaining their profits. The main issue and which is an important role is shipment and transportation consolidation. Transportation plays an important role in the movement of a product, and its availability at a specified time can lead to expensive repercussions, such as lost sales, customer dissatisfaction and production downtime [10]. In transportation, a lower level with larger shipping size encourages managers to depart more ships. This makes transportation as the most important single element in logistics costs for most firms [5].

The impact on these enormous costs makes companies compete to find effective systems. Today an effective transportation system seeks to maximize the value of its services by understanding the service needs of its customers, setting or negotiating prices high enough to cover the delivery costs incurred and then delivering the desired services as efficiently as possible [19]. Basically, the objectives of transportation efficiency should be centered on satisfying customers, minimizing costs and making a profit contribution, while maintaining competitiveness [20]. Improving cost efficiency can be made by several methods. But basically, the efforts can be made by reducing the shipping times and costs by increasing the various modes' compatibilities and by trying new mode of combinations [7].

System or software is used in the decision making process to achieve optimization. Logistics also applies a system in the effort to improve effectiveness that helps logistics managers in deciding carrier and shipping modes while minimizing transportation costs appropriately. Of course, the proper choice of a carrier can also significantly reduce shipping costs. Greater savings can be achieved by grouping customer orders properly to create optimal shipments [6].

Some researchers have conducted studies related to freight consolidation [17]. Systems are developed to combine and consolidate freight, that according to Hall [9] can be made by using three strategies of consolidation, i.e., inventory consolidation, vehicle consolidation and terminal consolidation. Meanwhile, according to Pooley and Stenger [14], to study the effects of freight consolidation, it can be made by structural simulation model. In addition to its effects and strategies, freight consolidation can also help enhancing environmental sustainability as well [11].

Packaging is the activity to wrap the export goods by using various types of packing materials and by considering the safety factors [16]. Packing can be by using carton, rack steel or container. The increase in global trade has resulted in the higher demand of containerization. Currently studies related to containerization focus on container loading and unloading optimization into the shipping vessels [24], pricing and utilization of reusable containers [3], quay crane scheduling [4] or container yard space optimization in the container depot or terminal [1]. To improve containerization it is required a good composition in the arrangements of goods in the rack so that they are not messy in the container. Shipping with containers has several advantages, for example, easy storage and transported that resulting reduced warehousing and transportation costs, lesser loading time, shorter transit time and minimize the risk of pilferage and damage during loading and unloading processes. Maximizing the efficiency of loading space utilization of the rack is the main concern in container loading processes [13, 24]. Miyamoto [12] in journal find that a container loading problem needs a procedure consist of how to locating objects that should be loaded into the rack.

The simulation methods consider the uncertain and stochastic factor and can deal with complex constraints in scheduling model [25]. In real life, the problem of container loading is very complex, therefore providing assistance in the form of computers or other equipment improves the ability to serve customers faster and improves the quality of services, as well as having many other benefits [20]. In this case, the use of software for optimization in increasing loading and transport is a radical step, which has huge impact in improving efficiency of loading layout. Yu and Qi [22] studied ways to improve the operational efficiency of inbound containers using simulation, whereas, Yun et al. [23] investigated the demand for empty containers and their expected costs using simulation-based optimization. Optimization software slashes the time it takes to work out the best solutions for the cargo by reducing the loading time and improving packaging decisions, where the answer arrives in minutes instead of hours or days. Loading plans, cutting patterns and packaging designs help to complete the task efficiently and the whole exercise is easy to understand. There are a number of software packages available to optimize the rack utilization, such as AutoLoadPro, MaxLoad®Pro, CubeMaster and Cargo Optimizer.

2.2. Methods

This study is intended to seek the level of efficiency for the most optimal container space utilization. It is conducted through packing optimization by comparing the calculations using software and conventional, to those included in the shipping processes.

Stages in the process of shipping goods related to the flow of goods loading done in accordance with the figure 1 below. In general, this stage begins with input specifications, loading options, loading results, preparation of loading and reporting plans. In this study, the calculation is focused on optimizing the loading of goods in the rack, which is an important factor in the optimization of shipping goods.

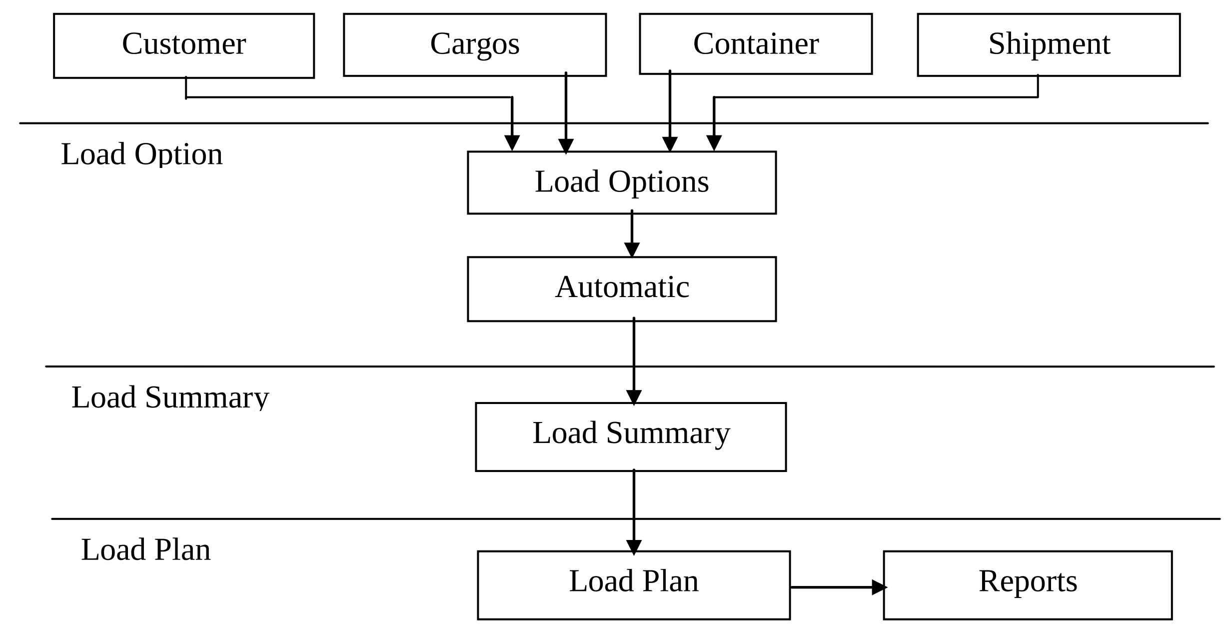

Figure 1: Calculation Stages on the Load Flow

The data collected in this study is quantitative data that is obtained and further processed in this study in the form of data volume of each product produced by an automotive company.

Data processing is made by using two softwares, namely QM for Windows and CubeMaster. QM for Windows is a computer program used to solve problems relating to quantitative methods, business management and operations research. This program is a combination of the previous programs, namely DS and POM for Windows, that there are more modules it provides than POM for Windows [21]. This program has several modules and in this study, the module used to solve the optimization in automotive company is an integer programming module. The QM for Windows consists of input and output. The input used in the optimization process is the objective function and the constraint equation, while the output produced is the number of product combinations. According to Hillier et al. in Triyanti, et al. [8], the mathematical model for integer programming is similar to the linear programming model, the difference being only the addition of one restriction that the variable must be an integer. Based on its variable, integer programs are divided into three types of models as follows:

1. Pure Integer programming
   This model expects all variables must take an integer value (positive integer or zero).
2. Mixed Integer programming
   This model expects only certain variables to be an integer, in other words not all variables are of integer value.
3. Zero One integer programming
   This model expects only zero or one for its variables. Generally used in decision making that requires an answer of "yes" or "no".

Mathematically, the model of integer programming equations is not different from the general model of linear programming which consists of a set of decision variables X1, X2, ..., Xn. The only difference is in the addition of one restriction that the variable must be an integer. The model of integer programming equations can be formulated as follows:

Maximum (or Minimum) Z = $C1X1 + C2X2 + \ldots + CnXn$ (1)

with constraints:

$A11X1 + A12X2 + \ldots.. + A1nXn \leq B1$ (2)

$A21X1 + A22X2 + \ldots.. + A2nXn \leq B2$ (3)

…

$Am1X1 + Am2X2 + \ldots.. + AmnXn \leq Bn$ (4)

$X1, X2, \ldots.., Xn = 0$ and integer (5)

Where :

Z	:	Optimized value (maximum or minimum)
Cn	:	Coefficient of objective function of every nth activity,
Xn	:	The nth activity that is carried out,
Amn	:	The number of m resources required to produce every nth output unit.
Bn	:	m resources available to allocate.
m	:	Various constraints of available resources.
n	:	Various kinds of alternative decision activities.

In addition to QM for Windows, another computer program namely CubeMaster is used. CubeMaster is a program that is used to help in solving problems in arranging items within the container for shipment. CubeMaster is a 3D-based graphics simulation program that can be used to help in resolving problems in suppy chain related to packing and loading of products [2]. This program offers five types of optimizations, namely carton optimization, truck optimization, air cargo optimization, pallet optimization and sea cargo optimization. The optimization type to be selected will be in according with the needs and types to be used for product loading.

The steps of data processing are as follows:

1) Formulate problems within the framework of integer programming.
   To formulate a problem using integer programming, it needs as follows:
   1. The decision variables
      The decision variables are the variables that describe completely the decisions to be made.
   2. The objective function
      The objective function is a linear equation (function) that includes the decision variables to be maximized (the volume of rack loading capacity) or to be minimized (the number of racks to be used).
   3. Limiters / constraints
      Constraints means any limitations or any situations that restricts the company's operations.
2) Write down the mathematical equations.
   After identifying the problem, the formula can be transformed into a mathematical equation. First, the decision variable to be symbolized with certain letters. The objective then can be transformed into a

mathematical symbol called the objective function. Constraints must also be transformed into a mathematical equation called a constraint equation.

3) Write down the formula into QM for Windows

After the objective function and the constraint equation of the existing problem are created, both are used as inputs in QM for Windows software. Previously note that there are several terms in the QM for Windows program associated with the optimization process, that is:

1. MAX : This option is selected at the beginning of the objective function to show the maximization function in the objective function.
2. MIN: Same as MAX command, just to show the minimization function.
3. Constraint: The constraint equation encountered in the optimization.

4) Interpretation of QM for Windows output

Once the input is processed in QM for Windows, it will generate output which is the optimal solution of the problems encountered. The next step to be taken after the output generated is to interpret the output. The integer programming module generates four outputs from the optimization process, i.e. :

1. Integer Programming Results Display

   It shows the calculation results in the form of optimum solution for each variable.
2. Iteration Results Display

   It shows the calculation results step by step (It appears when the computational problem to be solved is not complicated).
3. Original Problem Display with answer

   It shows the results of the computation along with the issues that are solved.
4. Graph Display

   It shows graphically, the results of LP computation. The graph will only appear when a two dimensional problem to be solved (can be depicted with a graph with the x and y axes).

5) Product loading simulation with CubeMaster

In addition to the optimization process, the rack loading problem should be simulated with simulation program to check the optimization result. In the optimization process, the number of optimal product combination loaded into the steel rack is the result of a theoretical approach, whereas in the simulation, an optimal product combination which can be loaded into the steel rack is the result of a technical approach in this study case concern.

3. Result and Discussion

3.1. Result

The formulation of the integer programming model in this study have the following assumptions: the internal dimensions are RV14 Rack : 1170 mm x 2270 mm x 1440 mm and RV5 Rack : 1170 mm x 2270 mm x 1090 mm. The decision variables are the products produced by automotive company suppliers with designs per model to be exported to Malaysia. The products consist of 20 parts. Each product is packed in a cardboard box. The parts will be delivered to the customers with LOT multiples. 1 LOT equals to 12 Units. The decision variables to be examined are shown in Table below.

Table 1: Decision Variables

Product	**Number**		
	3 Box	**2 Box**	**1 Box**
FIN ASSY-FR DOOR,LH1	X15		
BODY ASSY-AIR BAG ST2	X16		
CABLE ASSY-PKB,RR RH1		X7	
CABLE ASSY-PKB,RR RH2		X8	
PANEL ASSY-INST UPR1		X9	
CABLE ASSY-PKB,RR LH2		X18	

PIPE COMPL-FR COOLER2	X1
GLASS RUN-RR DOOR WD3	X2
FEEDER-ANT,B2	X3
STRIKER ASSY-RR SEAT1	X4
FIN ASSY-POWER WDW S4	X5
FIN ASSY-POWER WDW S5	X6
INSUL-HOOD1	X10
GLASS RUN-RR DOOR WD4	X11
MASK-INST,RH1	X12
FIN ASSY-POWER WDW S2	X13
COVER-3RD SEAT LEG,F1	X14
GLASS RUN-FR DOOR WD1	X17
CABLE COMPL-HOOD LOC1	X19
CABLE COMPL-FUEL OPN1	X20

The objective function is a mathematical formula that describes the objective of the company. The objective to be achieved by the company herein is the optimal volume. The model formulation of the objective function for this problem is as follows:

Maximum $Z = \sum_{i=1}^{30} CiXi$ (6)

Notes :

Z = The objective function value / volume maximization (m^3)

Ci = Contribution of i-th volume

Xi = Quantity of i-th products

i = Products group

This optimization purpose is to optimize the volume inside the steel rack so that the better the composition in the steel rack will affect to the quantity of steel rack and container needed. After the benefit value of each volume of each decision is known, then the objective of the function can be formulated as follows (in m^3):

Max $Z = 0.33075X1 + 1.24025X2 + 0.0570515X3 + 0.017472X4 + 0.04095X5 + 0.04095X6 + 0.0000304X7 + 0.0000304X8 + 0.2158065X9 + 0.000036X10 + 0.286X11 + 0.0306425X12 + 0.04095X13 + 0.015548X14 + 0.42588X15 + 0.101177X16 + 0.1929375X17 + 0.000036X18 + 0.000024X19 + 0.000024X2$ (7)

The company faces a problem of product shipment to its customers in Malaysia. It uses racks for the shipment but there are some limitations with the loading volume. The rack volume and the minimum limit in each delivery for all parts are 12 Units. Then, the formulation of the model is as follows:

Rack volume constraint

The company in distributing its products to the customers uses rack modules. The company has standardized racks for export shipment. The racks are made of steel and returnable. The characteristics of the racks are as follows:

1) They are quite strong, made of steel and can be used repeatedly;
2) Designed specifically to carry goods with any modes of transportation available;
3) Designed in such a way that makes it easy for loading or unloading with Internal Volume of at least RV14 Rack: 3.190 m^3 and RV5 Rack: 2.325 m^3.

The Rack's volume is limited. RV14 Rack volume is 1170 mm x 2270 mm x 1440 mm and RV5 Rack volume is 1170 mm x 2270 mm x 1090 mm. The internal dimensions of the rack are: RV14 Rack is 1109 mm x 2230 mm x 1290 mm and RV5 Rack is 1109 mm x 2230 mm x 940 mm. Every product is packed before loaded into the racks. The packages are in various dimensions. The dimension of each package will be the coefficient for each decision variable in the rack volume constraint equation. The dimension for each decision variable is shown in Table below.

Table 2 Coefficient of Form Dimensions for Decision Variables

Decision Variable	Product	Quantity Box	Volume of Packaging (m^3)
X1	PIPE COMPL-FR COOLER2	1	0.33075
X2	GLASS RUN-RR DOOR WD3	1	1.24025
X3	FEEDER-ANT,B2	1	0.0570515
X4	STRIKER ASSY-RR SEAT1	1	0.017472
X5	FIN ASSY-POWER WDW S4	1	0.04095
X6	FIN ASSY-POWER WDW S5	1	0.04095
X7	CABLE ASSY-PKB,RR RH1	2	0.0000304
X8	CABLE ASSY-PKB,RR RH2	2	0.0000304
X9	PANEL ASSY-INST UPR1	2	0.2158065
X10	INSUL-HOOD1	1	0.000036
X11	GLASS RUN-RR DOOR WD4	1	0.286
X12	MASK-INST,RH1	1	0.0306425
X13	FIN ASSY-POWER WDW S2	1	0.04095
X14	COVER-3RD SEAT LEG,F1	1	0.015548
X15	FIN ASSY-FR DOOR,LH1	3	0.42588
X16	BODY ASSY-AIR BAG ST2	3	0.101177
X17	GLASS RUN-FR DOOR WD1	1	0.1929375
X18	CABLE ASSY-PKB,RR LH2	2	0.000036
X19	CABLE COMPL-HOOD LOC1	1	0.000024
X20	CABLE COMPL-FUEL OPN1	1	0.000024

Based on the form coefficient data for each known decision and volume steel rack variable, the constraint equation for steel rack volume can be formulated as follows (in m^3):

$$0.33075X1 + 1.24025X2 + 0.0570515X3 + 0.017472X4 + 0.04095X5 + 0.04095X6 + 0.0000304X7 + 0.0000304X8 + 0.2158065X9 + 0.000036X10 + 0.286X11 + 0.0306425X12 + 0.04095X13 + 0.015548X14 + 0.42588X15 + 0.101177X16 + 0.1929375X17 + 0.000036X18 + 0.000024X19 + 0.000024X20 \leq 2.3246858 \quad (8)$$

$$0.33075X1 + 1.24025X2 + 0.0570515X3 + 0.017472X4 + 0.04095X5 + 0.04095X6 + 0.0000304X7 + 0.0000304X8 + 0.2158065X9 + 0.000036X10 + 0.286X11 + 0.0306425X12 + 0.04095X13 + 0.015548X14 + 0.42588X15 + 0.101177X16 + 0.1929375X17 + 0.000036X18 + 0.000024X19 + 0.000024X20 \leq 3.1902603 \quad (9)$$

Shipment will be for 20 parts only. Each part will be shipped only when it is minimum for 12 Units or 1 Lot. The following parts have a maximum box limit due to the size of the order using Lot unit. Based on the quantity for both products, the constraint equation can formulate as follows (in package):

$$X1 \leq 1 \quad (10)$$
$$X2 \leq 1 \quad (11)$$
$$X3 \leq 1 \quad (12)$$
$$X4 \leq 1 \quad (13)$$
$$X5 \leq 1 \quad (14)$$
$$X6 \leq 1 \quad (15)$$
$$X7 \leq 2 \quad (16)$$
$$X8 \leq 2 \quad (17)$$
$$X9 \leq 2 \quad (18)$$
$$X10 \leq 1 \quad (19)$$
$$X11 \leq 1 \quad (20)$$
$$X12 \leq 1 \quad (21)$$
$$X13 \leq 1 \quad (22)$$

$$X14 \leq 1 \quad (23)$$
$$X15 \leq 3 \quad (24)$$
$$X16 \leq 3 \quad (25)$$
$$X17 \leq 1 \quad (26)$$
$$X18 \leq 2 \quad (27)$$
$$X19 \leq 1 \quad (28)$$
$$X20 \leq 1 \quad (29)$$

3.2. Discussion

In this study, the decision variable, that the value to be seeks for, is the number of product combinations that will be a reference for the automotive company in its shipment. The most optimal simulation will be used as a reference for its packing standard operating procedure. The simulation results are expected to give optimum gain value compared to other combinations. In this study, the whole 20 parts involved in the simulation must go into the pallet and nothing left unloaded. The optimization volume should refer to RV5. After the first process, check what products can be loaded in the first RV5 rack. The remaining items unloaded into the first RV5 will be re-simulated into the RV5. If they cannot be loaded into RV5 then the rack will be replaced with RV14 for optimization in the next experiment.

In the first simulation, the input is for 20 parts at once into QM for windows, to find out the most optimal combination for RV5 rack. Based on the results of processing the optimization using QM for Windows, it is found the optimal combination of products for each shipment is 2 Boxes of X2, 1 Box of X4, 2 Boxes of X7, 2 Boxes of X8, 1 Box of X10, 1 Box of X14, 2 Boxes of X15, 1 Box of X17, 2 Boxes of X18, 1 Box of X19, 1 Box of X20 for RV5 pallet module. RV5 is used in the second simulation since the rest of products cannot be accommodated with the RV5 pallet. In the second simulation using RV5 the combinations are as follows: 1 Box of X1, 1 Box of X3, 1 Box of X5, 1 Box of X6, 2 Boxes of X9, 1 Box of X11, 1 Box of X12, 1 Box of X12, 1 Box of X13, 1 Box of X15, 1 Box of X16. The output of the processing with the help of QM for windows is presented in the Table below.

Table 3: Optimization Result 1st Operation QM for Windows

RV5	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20		
Max	0.33	1.24	0.06	0.02	0.04	0.04	0.00	0.00	0.22	0.00	0.29	0.03	0.04	0.02	0.43	0.10	0.19	0.00	0.00	0.00		
Con 1	0.33	1.24	0.06	0.02	0.04	0.04	0.00	0.00	0.22	0.00	0.29	0.03	0.04	0.02	0.43	0.10	0.19	0.00	0.00	0.00	<=	2.33
Con 2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<=	1
Con 3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<=	1
Con 4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<=	1
Con 5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<=	1
Con 6	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<=	1
Con 7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<=	1
Con 8	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	<=	2
Con 9	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	<=	2
Con 10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	<=	2
Con 11	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	<=	1
Con 12	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	<=	1
Con 13	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	<=	1
Con 14	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	<=	1
Con 15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	<=	1
Con 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	<=	3
Con 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	<=	3
Con 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	<=	1
Con 19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	<=	2
Con 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	<=	1
Con 21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	<=	1
Var. type	Integer																					
Solution	0	1	0	1	0	0	2	2	0	1	0	0	0	1	2	0	1	2	1	1	Z	2.32

Table 4: Optimization Result 2nd Operation QM for Windows

RV5	X1	X3	X5	X6	X9	X11	X12	X13	X15	X16		
Max	0.33	0.06	0.04	0.04	0.22	0.29	0.03	0.04	0.43	0.1		
Con 1	0.33	0.06	0.04	0.04	0.22	0.29	0.03	0.04	0.43	0.1	<=	3.19
Con 2	1	0	0	0	0	0	0	0	0	0	<=	1
Con 3	0	1	0	0	0	0	0	0	0	0	<=	1
Con 4	0	0	1	0	0	0	0	0	0	0	<=	1
Con 5	0	0	0	1	0	0	0	0	0	0	<=	1
Con 6	0	0	0	0	1	0	0	0	0	0	<=	2
Con 7	0	0	0	0	0	1	0	0	0	0	<=	1
Con 8	0	0	0	0	0	0	1	0	0	0	<=	1
Con 9	0	0	0	0	0	0	0	1	0	0	<=	1
Con 10	0	0	0	0	0	0	0	0	1	0	<=	1
Con 11	0	0	0	0	0	0	0	0	0	1	<=	3
Var. type	Integer											
Solution	1	1	1	1	2	1	1	1	1	3	Z	2

The simulation of loading into rack in this study will use CubeMaster. The simulation processing will be by input the size of pallet and part according to the results of the previous optimization. The simulation will also specify the orientation of goods, whether it can be tilted or must face up. The simulation will be done several times to find the most appropriate position in the rack, and all parts are accommodated into the rack with the most optimal rack space utilization. After several simulations, a combination was found that met the criteria. Some constraints are found during loading into the rack. Any items made of glasses must bein the position of facing up. But there is no constraint with the rest of the items that they can sit in six different positions. The simulation of loading into the rack with the help of CubeMaster generates the layout of products sitting in the rack. The first optimized calculation result can be calculated to achieve 99.57% steel rack efficiency rating for 1st RV5 steel rack and 86% for 2nd RV5 steel rack type. It is more efficient than the utilization of space volume by the company in the conventional operations which is only 80% of the space volume. Total space utilization in RV5 reaches 2.32 m^3 out of the rack's total space of 2.33 m^3. Meanwhile, the total space utilization in RV14 reaches 2 m^3 out of the rack's total space of 2.32 m^3.

However, in actual mapping there is a gap between the optimization by using integer linear programming with QM for Window and by visual simulation with Cubemaster software. In the simulation using Cubemaster, the second combination for RV5 cannot accommodate all items; therefore, RV14 should be used. As the result, the space utilization of the rack decreases from 86.20% to 62.69%. The final result with a combination of products from the second simulation of RV5 and RV14 racks is shown in Figure below.

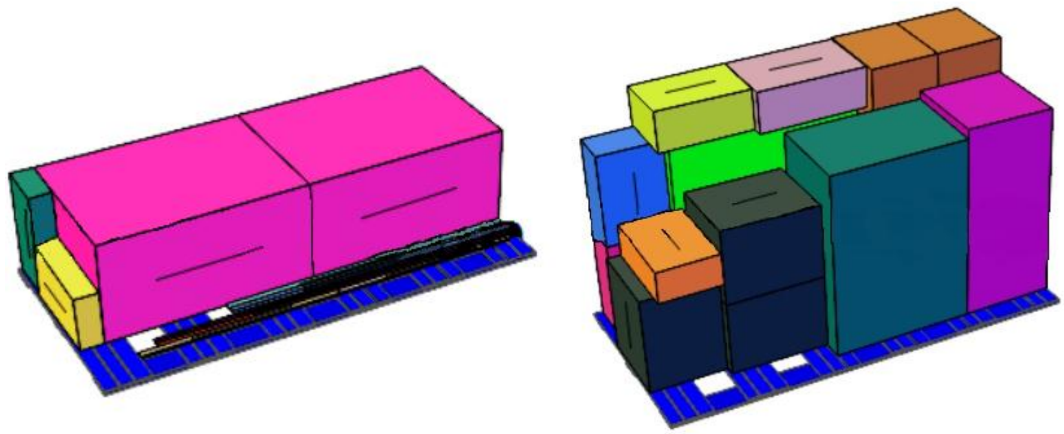

Figure 2: The final conditions of the steel rack in the simulation process

The following is a list of combination of products and optimizations from both racks.

Table 5: Product Combinations of Optimization and Simulation Results

Product	Quantity Box	Combination	
		RV5	RV14
GLASS RUN-RR DOOR WD3	1	X2	
STRIKER ASSY-RR SEAT1	1	X4	
CABLE ASSY-PKB,RR RH1	2	X7	
CABLE ASSY-PKB,RR RH2	2	X8	
INSUL-HOOD1	1	X10	
COVER-3RD SEAT LEG,F1	1	X14	
FIN ASSY-FR DOOR,LH1	3	X15	X15
GLASS RUN-FR DOOR WD1	1	X17	
CABLE ASSY-PKB,RR LH2	2	X18	
CABLE COMPL-HOOD LOC1	1	X19	
CABLE COMPL-FUEL OPN1	1	X20	
PIPE COMPL-FR COOLER2	1		X1
FEEDER-ANT,B2	1		X3
FIN ASSY-POWER WDW S4	1		X5
FIN ASSY-POWER WDW S5	1		X6
PANEL ASSY-INST UPR1	2		X9
GLASS RUN-RR DOOR WD4	1		X11
MASK-INST,RH1	1		X12
FIN ASSY-POWER WDW S2	1		X13
BODY ASSY-AIR BAG ST2	3		X16

Based on Table above, there are differences in the combination obtained from the optimization and obtained from the simulation. It shows that optimization generates a greater efficiency of rack space utilization. The optimization is achieved by combining products loading by theoretical approach, while the simulation has lower efficiency of rack space utilization. This study shows that the optimization by using dimensions data for computation processing will combine products based on volume only and does not include a simulation on how to load Boxes into the rack. This study finds that combination of products generated by visual simulation with Cubemaster will be preferable as a recommendation for the company rather than combination of products generated by optimization processing. It is because the combination of products generated by visual simulation is obtained based on technical approach, and it is more applicable in the real situation of the company.

4. Conclusion

The simulation for optimization of product loading into the racks by the automotive company provide a better efficiency of rack space utilization compared to the efficiency obtained from the conventional method. Optimal product combinations for each shipment are as follows: 2 Boxes of X2, 1 Box of X4, 2 Boxes of X7, 2 Boxes of X8, 1 Box of X10, 1 Box of X14, 2 Boxes of X15, 1 Box of X17, 2 Boxes of X18, 1 Box of X19, 1 Box of X20 for RV5 pallet module. RV5 is used in the second simulation since the rest of products cannot be accommodated with the RV5 pallet. In the second simulation using RV5 the combinations are as follows: 1 Box of X1, 1 Box of X3, 1 Box of X5, 1 Box of X6, 2 Boxes of X9, 1 Box of X11, 1 Box of X12, 1 Box of X12, 1 Box of X13, 1 Box of X15, 1 Box of X16.

However, in actual mapping there is a gap between the optimization by using integer linear programming with QM for Window and by visual simulation with Cubemaster software. In the simulation using Cubemaster, the second combination for RV5 cannot accommodate all items; therefore, RV14 should be used. As the result, the space utilization of the rack decreases from 86.20% to 62.69%.

This study shows that the optimization by using dimensions data for computation processing will combine products based on volume only and does not include a simulation on how to load Boxes into the rack. This study finds that combination of products generated by visual simulation with Cubemaster will be preferable as a recommendation for the company rather than combination of products generated by optimization processing. It is because the combination of products generated by visual simulation is obtained based on technical approach, and it is more applicable in the real situation of the company.

Based on this study, here is some suggestions for the company: a combination of the number of products to be loaded into the steel rack that will increase profits and better packaging using cardboard paper to minimize damage during shipment. While, suggestion for further research is to add one constraint equation in the optimization processing that can improve the optimization. The addition of the new constraint equation is expected to generate output that is not of great difference from the output generated by simulation.

The uses of optimization processing in actual practices still will be required for finding any items that is potential to be included into a particular packing module. However, in the next step simulation must be made to examine if all items selected can be loaded appropriately into the module. This is applicable when the company has various products that the shipment can be consolidated in a certain module.

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