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RESEARCH ARTICLE OPEN ACCESS

OPTIMIZING PORTER ASSIGNMENTS IN HOSPITAL: A MATHEMATICAL MODELING APPROACH FOR WORKLOAD BALANCING

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ABSTRACT

This case study addresses the staffing challenges faced by a hospital's porter service, which is currently insufficient to meet patient needs effectively. Due to the lack of a systematic task assignment mechanism, the head of the porters' center has had to manage patient transport manually, leading to unequal workload distribution among porters. This research aims to rectify this operational issue by developing a mathematical model and a user-friendly program for optimizing porter assignments. The methodology includes extensive data collection on existing protocols and factors affecting operations. A mathematical model is formulated with the objective of minimizing monthly workload deviations among porters. The model is executed using Excel Solver, producing an optimal assignment solution. Additionally, Visual Basic for Applications (VBA) in Excel is utilized to create a practical program for real-world application. A quantitative comparison of the standard deviation in cumulative workload from September 2022 reveals a significant improvement: the proposed program reduced the standard deviation by 5,907 seconds, or 76.17%. This outcome highlights the effectiveness of the new solution in achieving a more balanced distribution of porter assignments, thereby enhancing operational efficiency.

I. INTRODUCTION

Due to the recent elevation of the case study hospital to the status of a central healthcare facility catering to patient referrals from hospitals within the Chiang Mai, Lamphun, and Mae Hong Son provinces in Thailand, accompanied by its advancement as a high-level center of expertise in accident care, the hospital has garnered approval for a substantial expansion of its bed capacity to 700 beds in the fiscal year 2022. Concomitantly, there has been a marked escalation in the utilization rates.

The extant responsibilities of porters at the case study hospital encompass the intricate coordination of patient movements within the wheelchair and stretcher services, inclusive of a spectrum of associated tasks. A pivotal facet of the porter's duties resides in their imperative to function within stringent temporal constraints while managing a sizable and demanding workload. This is precipitated by the exigency for porters to promptly furnish services to incoming patients, facilitating their expeditious transfer to diagnostic examination rooms or designated patient wards.

An examination of hospital data reveals a discernible and escalating influx of patients seeking treatment at the case study hospital annually. Within this cohort, a subset necessitates assistance in their mobility to access different departments within the hospital for requisite medical interventions. The responsibility for patient transport falls under the purview of the "Porter Center," currently operational at six strategic locations, encompassing the Accident Building, Emergency Room (ER), Outpatient Department (OPD), as well as specific points such as X-RAY, MRI, CT, and U/S. Additionally, the porter services extend to the Inpatient Department (IPD).

Each porter contends with a substantial daily workload, heightened by the increased demand for services and the multifaceted nature of assigned tasks. Nevertheless, the prevailing task assignment framework lacks a transparent mechanism for the equitable distribution of responsibilities among porters, resulting in an imbalanced workload distribution. Consequently, some porters bear a disproportionate burden, leading to fatigue due to the physical demands involved in patient transport, preparatory activities, and sanitation tasks. This is particularly pronounced for porters handling patients with substantial body weight, predisposing them to fatigue or potential musculoskeletal injury. These challenges have tangible implications, resulting in service delays that impact both patient experience and hospital operational efficiency.

The task assignment predicament aims at optimizing the allocation of available resources to maximize benefits. Task assignment is a methodological process in problem-solving to find the most appropriate solution. Ordinarily, task assignment is performed by supervisors, and decisions are influenced by their personal perspectives. However, reliance on personal perspectives may lead to an inequitable distribution of tasks among porters. This necessitates the application of task assignment algorithms to enhance work efficiency and minimize work duration for each porter.

Additionally, this research conducted a root cause analysis of the task assignment problem for porters at the case study hospital by studying the distribution data using the Why-Why Analysis tool. The results are elucidated in Figure 1.

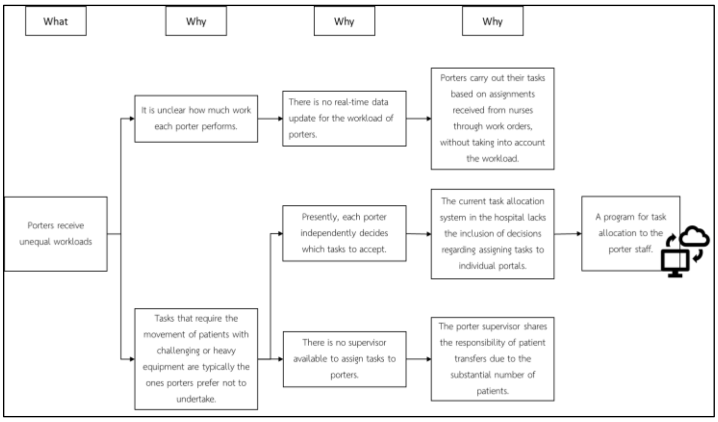

Figure 1: Why-Why analysis chart for the issue of porters' work assignment.
Source: Authors, (2024).

Therefore, this research proposes the utilization of Linear Programming as a tool to address task assignment problems. Linear Programming is a problem-solving tool in Operations Research, employing mathematical models to assist in problem-solving. It is effective in covering problems with limited resources and providing optimal results. This research applies Excel Solver as a software tool to solve the task assignment problem, utilizing mathematical models to prescribe conditions for porter task assignments. The mathematical model aims to propose the absolute cumulative workload deviation of porters on a daily basis as the objective function. Moreover, this research employs Visual Basic for Applications (VBA) to create a program for decision-making in task assignments to porters, aimed at achieving optimal workload balance.

II. THEORETICAL REFERENCE

In recent years, there has been a significant focus on applying mathematical modeling and optimization techniques in the healthcare sector [1], particularly in the domains of workforce scheduling and task assignment. This literature review provides a comprehensive overview, shedding light on the role of mathematical models in optimizing healthcare operations, with a specific focus on nurse scheduling and task assignment problems. [2] contribute to this field by applying mathematical modeling techniques to nurse scheduling at Surasat General Hospital, aligning with global efforts to ensure efficient nurse scheduling for high-quality patient care and the well-being of healthcare professionals. The literature review indicates a growing interest in utilizing mathematical models to optimize healthcare operations, considering factors such as staff availability, skill mix, and patient demand.[3], [4] provide valuable insights into daily patient-nurse assignments and load-balancing nurse-to-patient assignments, respectively. The former introduces Constraint Programming (CP) models, enhancing scalability and accuracy, while the latter emphasizes the superiority of Constraint Programming over Mixed-Integer Quadratic Programming (MIQP) in addressing workload variance. Additionally, other researchers, including [5-7] contribute to the discourse on nurse assignment.

The application of optimization extends to ambulance transports, as shown by [8], addressing the challenge of hospital overloading during unusual demand shifts in emergency medical services (EMS) systems. They propose a load-balancing optimization algorithm developed in collaboration with Columbia University and the Fire Department of the City of New York, emphasizing a proactive approach to prevent hospital overload during unexpected incidents. [9] address real-time optimization challenges in Emergency Medical Services (EMS) with a survival-based framework, focusing on maximizing patient survival while balancing EMS workload. Their approach, validated in a New York City case study, demonstrates significant improvements in response times for life-threatening emergencies, efficient workload balancing, and potential cost savings through integrating ride-hailing services.

To apply optimization techniques to porter assignment in hospitals, [10] extend mathematical modeling to task assignment and distribution for hospital porters, emphasizing the shift from traditional scheduling problems to broader resource allocation challenges within healthcare settings. This underscores the importance of workload balance for both nursing staff and ancillary services, highlighting the holistic nature of healthcare operations. [11] emphasize the crucial role of porters in hospital operations and address transparency in their movements through an Indoor Location-Based Porter Management System (LOPS). This system provides real-time location information to the dispatcher, enabling hospitals to enhance porter team efficiency and streamline daily operations for improved patient care. [12] highlight critical considerations in patient transportation within hospitals, integrating the needs of hospital managers, patients, and porters into a mathematical model. The tailored Tabu search algorithm used in solving the model demonstrates efficiency, producing high-quality solutions in a short time frame that outperform those generated by typical real-world planning approaches. The research emphasizes the trade-off between the interests of hospital managers, patients, and porters, underscoring the significance of holistic and optimized patient transport systems in healthcare settings.

In conclusion, these studies collectively reflect a growing trend in healthcare operations research, emphasizing the need for systematic, quantitative approaches to address scheduling, task assignment, and resource optimization challenges. The literature suggests that mathematical modeling, particularly linear programming and other optimization techniques, is increasingly becoming integral to decision-making processes in healthcare operations. This trend aligns with the broader paradigm shift towards data-driven decision-making and evidence-based management in healthcare, contributing to a broader understanding of the role of quantitative methods in enhancing efficiency and quality of service delivery in healthcare and other industries.

III. MATERIALS AND METHODS

In this research, the methodology comprises a multi-step investigation and analysis approach to address the task assignment and workload distribution challenges faced by hospital attendants at the case study hospital in Chiang Mai. The methodology is structured into distinct sections:

1. Examination of Current Attendant Workflow at hospital.

The initial phase of this research focused on analyzing the current workflow and assignment protocols for attendants at the case study hospital, located in Chiang Mai. The investigation encompassed various aspects such as task delegation mechanisms, procedures from task assignment to patient transfer completion, the daily workforce count, equipment utilization during patient transfers, established routes for attendants, location mapping of the attendant center, and overall hospital infrastructure. Additionally, this study explored various contributory factors leading to delays in patient transfers. Data was primarily sourced through consultations with the head of the attendant center at the case study hospital and supplemented with relevant prior research.

2. Exploration of Mathematical Modeling Principles and Excel Solver Application.

The research subsequently delved into studying pertinent mathematical modeling theories to facilitate the development of an appropriate model for task assignment optimization. Utilizing Microsoft's Excel Solver tool, the study aimed to generate objective functions and constraint equations essential for solving the attendant task distribution problem. Furthermore, the research incorporated Visual Basic for Applications (VBA) within the Microsoft Excel environment to formulate and implement the requisite codebase.

3. Data Collection.

A meticulous data collection process ensued, focusing on gathering detailed information regarding attendant workflows, equipment usage, established patient transfer routes, and attendant work schedules. The objective was to identify prevalent operational challenges and analyze underlying causal factors. This comprehensive data served as the foundation for subsequent mathematical modeling efforts.

4. Mathematical Model Development for Problem Resolution.

The subsequent phase of the research utilized equipment usability as a metric to evaluate the complexity of attendant tasks. A mathematical model was developed to quantify the cumulative workload for each attendant based on the time-intensive nature of assigned tasks. This model employed the Mean Deviation (M.D.) formula to quantify the absolute average deviation from the mean workload.

5. Validation of the Mathematical Model.

To ascertain the efficacy and accuracy of the developed mathematical model, a validation process was undertaken. Small-scale data simulations were conducted to test the model's capabilities in optimizing task assignments and reducing workload discrepancies effectively.

6. Program Development for Attendant Task Allocation.

This phase involved the creation of a user-friendly program, incorporating the previously developed mathematical model within a Microsoft Excel VBA framework. The program aimed to automate task assignments for attendants at the case study hospital, ensuring equitable workload distribution among staff members.

7. Results Analysis and Conclusion.

The penultimate phase entailed a comprehensive analysis of outcomes derived from comparing standardized workload data with model-generated results. The research aimed to determine the model's efficacy in minimizing workload standard deviations and enhancing operational efficiency. Finally, this research culminated in summarizing the achieved milestones, compiling findings

IV. RESULTS AND DISCUSSIONS

IV.1 DATA COLLECTION

1. Attendant Work Log Data Collection

Data was gathered from attendants at the case study hospital, encompassing their work logs, which included information such as attendant names, patient transfer equipment used, additional transfer equipment utilized, the respective origin and destination departments involved in patient transfers, and the corresponding time expended on each patient transfer. A total of 2,428 data sets were amassed to facilitate the computation of workload weighting.

2. Building-to-Building Distance Data Collection

Building-to-building distances within the case study hospital were measured utilizing Google Maps. In addition, real-time measurements of distances were obtained, extending from the building's front to the elevator, employing specialized tools to offer a pragmatic representation of travel distances. Average distances were calculated, and a conversion to vertical distances was conducted by adopting a standard height of 3 meters per floor.

IV.2 MATHEMATICAL MODEL

The mathematical model, concerning the objective function, aims to minimize the absolute average deviation of the workload of attendants each month. The workload is evaluated based on the distance and the speed of the equipment used in patient transfers, including additional transfer accessories. The transformation of distances and the equipment used in patient transfers into a unified unit of measurement is necessary for a comprehensive assessment of the cumulative workload of attendants. This transformation ensures a clearer representation of workload weights in terms of time.

1. Calculating the Average Speed of Patient Transfer Equipment and Additional Transfer Accessories for Cumulative Workload Assessment:

To compute the average speed, the distance between departments, obtained through data collection, is utilized along with the time spent on tasks. The time data retrieved from the system is initially in Epoch Time format.

$$\frac{\text{Epoch Time}}{86{,}400} + 25{,}569 \tag{1}$$

Subsequently, it is converted into standard time format. After the conversion, the time is represented in regular seconds, enabling the calculation of the average speed of patient transfer equipment and additional transfer accessories used in patient transfers as shown in Table 1.

Table 1: Average speed ratios for the 7 criteria.

Criteria	Overall Speed Ratio	True Instances	Average Speed (m/s)
Wheelchair	211.57	160	1.32
Wheelchair + Saltwater/Rubber Tube/Foley Catheter	14.51	19	0.76
Crutch	68.66	97	0.71
Crutch + Saltwater/Rubber Tube/Foley Catheter	56.37	92	0.61
Crutch + Ventilator	2.90	5	0.58
Crutch + O2	9.92	31	0.32
Crutch + Over	1.57	8	0.20

Source: Authors, (2024).

2. Mathematical Model Using the Absolute Average Deviation Component:

Indices

i : Set of attendants (i = 1, 2, …, n)

j : Set of assigned tasks (j = 1, 2, .., m)

k : Set of workdays (k = 1, 2, …, k)

Parameters

w_{ij}^{k}: Cumulative workload of attendant i assigned to task j accumulated from day 1 to day k.

mean^{k}: The average cumulative working time of attendants at present

e_i: Deviation value of attendant i.

Decision Variable

x_{ij} : Equals 1 when attendant i is assigned task j; otherwise, it is 0.

e_i^{+} : Deviation value of attendant i when e_i is greater than 0

e_i^{-} : Deviation value of attendant i when e_i is less than 0

Objective function

$$Min\ Z = \frac{\sum_{i=1}^{n} |e_i|}{n} \quad (2)$$

Constraints

$$e_i = mean^k - \sum_{j=1}^{m} w_{ij}^{k} x_{ij} \quad \forall_{i,k} \quad (3)$$

$$\sum_{i=1}^{n} x_{ij} = 1 \quad \forall_j \quad (4)$$

$$\sum_{j=1}^{m} x_{ij} = 1 \quad \forall_i \quad (5)$$

$$x_{ij} = \{0,1\} \quad \forall_{i,j} \quad (6)$$

Equation (2) presents the objective function with the aim of finding the absolute deviation average of cumulative working time for the attendant with the lowest value. This equation is derived from the absolute deviation average equation, where the variable e_i can be obtained from the difference between the average cumulative workload of all attendants on day k and the cumulative workload of attendant i performing task j from day 1 to k as shown in Equation (3). Regarding the constraint equations, they enforce that each task is assigned to only one attendant, expressed in Equation (4) , and that each attendant must be assigned one task. Since the system involves assigning tasks sequentially, additional tasks are created equal to the number of attendants. These artificially generated tasks facilitate the optimization process of the Hungarian method, as outlined in Equations (5) . The decision variable (x_{ij}) is binary, reflecting the decision to perform or not perform a task, expressed in Equation (6).

Based on the proposed mathematical model, it is observed that the absolute deviation of attendant i (e_i) is subject to absolute value, indicating that e_i can be either positive or negative. To conform to the standard format of linear programming problems, the variable e_i is transformed into $e_i = e_i^{+} - e_i^{-}$. To achieve this transformation, it is required that both e_i^{+} and e_i^{-} are greater than or equal to 0, as stated in Equations (12) and (13). In summary, the objective function aims to minimize the sum of absolute workload deviations for each attendant in each month divided by the total number of attendants (n). Therefore, the reformulation of mathematical model is presented as follows.

Objective function

$$Min\ Z = \frac{\sum_{i=1}^{n} (e_i^{+} + e_i^{-})}{n} \quad (7)$$

Constraints

$$e_i^{+} - e_i^{-} + \sum_{j=1}^{m} w_{ij}^{k} x_{ij} = mean^k \quad \forall_{i,k} \quad (8)$$

$$\sum_{i=1}^{n} x_{ij} = 1 \quad \forall_j \quad (9)$$

$$\sum_{j=1}^{m} x_{ij} = 1 \quad \forall_i \quad (10)$$

$$x_{ij} = \{0,1\} \quad \forall_{i,j} \quad (11)$$

$$e_i^{+} \geq 0 \quad \forall_i \quad (12)$$

$$e_i^{-} \geq 0 \quad \forall_i \quad (13)$$

IV.3 MODEL VALIDATION

In the validation phase of the mathematical model, the accuracy of the mathematical model and the constraint equations used to solve the problem is examined to determine if tasks can be assigned to attendants to achieve balance. This involves simulating small-scale data to test the mathematical model, allowing it to produce results more efficiently. In this section, Microsoft Excel Solver is employed as a tool for testing. The objective function, decision variables, and various constraints of the Solver are specified. The objective function aims to minimize the absolute deviation average of cumulative workload for attendants in each month. The Microsoft Excel Solver is used to test whether the mathematical model can efficiently allocate tasks to attendants while achieving the minimum absolute deviation average of cumulative workload. This validation process ensures that the model accurately represents the problem and can provide optimal solutions.

IV.4 PROBLEM DEVELOPMENT

In the program development section, the researchers opted to use Microsoft Excel as their programming tool for allocating tasks to hospital attendants at the case study hospital, aiming to achieve a balanced workload. Microsoft Excel allows the integration of Visual Basic for Applications (VBA) code into its spreadsheet application, facilitating the creation of a user-friendly program. This program, once developed, will automate the task allocation process based on the mathematical model created.

The researchers designed the program using VBA with the objective of creating a systematic and user-friendly tool for practical use. The program's workflow is illustrated in Figure 2.

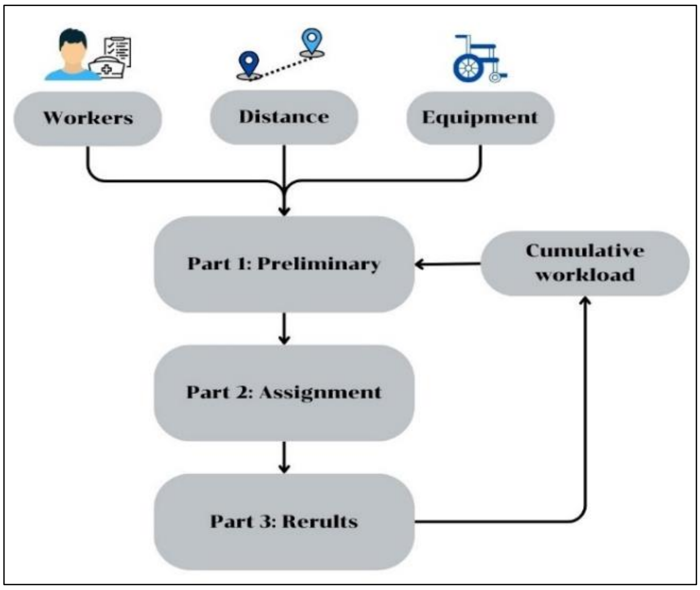

Figure 2: Workflow of the program.
Source: Authors, (2024).

The program is divided into three main parts:

Part 1: Preliminary

This part is responsible for data input, including the list of attending staff, the origin and destination departments for patient transfers, and the equipment used. It calculates the workload based on the distance traveled, equipment speed, and assigns this workload to be used in the task assignment process in Part 2.

Part 2: Assignment

This section utilizes the mathematical model to allocate tasks. It displays the assignment results from the Solver tool, showing which attendant is assigned which task and the corresponding workload. The results are then sent to Part 3.

Part 3: Results

This part displays the task assignment results obtained from Part 2. The results are added to the cumulative workload from previous rounds, and the new cumulative workload is sent back to Part 1 to inform task assignment decisions in the next round.

The three-part structure ensures a clear and organized workflow for the program, making it efficient and user-friendly for real-world applications.

IV.5 RESULTS ANALYSIS

The obtained data is subjected to further analysis, focusing on the results obtained from the actual work records of attendants who received task assignments. This data has been previously collected for the month of September (2022), consisting of a total of 456 records. The information includes the names of assigned attendants, the origin and destination departments for patient transfers, as well as the equipment used for the transfers, including auxiliary equipment. This data is input into a program to calculate the workload for each task. Subsequently, the calculated workload values are used to update the cumulative workload of each attendant. The cumulative workload obtained from task assignments using the old method is then compared with the cumulative workload obtained from task assignments using the mathematical model created by the Excel Solver tool. The results are recorded and presented in Table 2 for further analysis.

In scrutinizing Table 2 and Figure 3, a conspicuous observation emerges regarding the standard deviation values of cumulative workload among transport staff members. Specifically, the standard deviation associated with the conventional task assignment method stands at 7,754 seconds, eclipsing the analogous metric derived from the simplistic program, which registers at 1,847 seconds. This dichotomy underscores the superior equilibrium achieved by the program in workload distribution during the month of September compared to the traditional approach. Furthermore, discernible workload variations among staff members can be attributed to discrepancies in the number of workdays for certain individuals during that month.

In the subsequent analysis, a robust statistical examination was undertaken to assess the statistical significance of the difference in standard deviations in cumulative workloads between the traditional assignment method and the utilization of the straightforward program. The null hypothesis (H_0) posits the equality of standard deviations ($\sigma_1 = \sigma_2$), while the alternative hypothesis (H_1) asserts that the standard deviation associated with the traditional method surpasses that of the uncomplicated program ($\sigma_1 > \sigma_2$).

The examination of cumulative workload data for hospital transport staff at the case study hospital during September has revealed noteworthy insights. The conventional assignment method yielded a variance of 60, 120 and 711 in cumulative workloads, while the utilization of a program for task assignments resulted in a significantly lower variance of 3, 412, and 865. A meticulous comparative analysis of these cumulative workload variances indicates a profound statistical impact on the workload distribution among hospital transport staff.

Table 2: Comparison of task assignment results between the traditional method and after implementing the morning and afternoon shifts model in august, 2022.

Staff First Name	The actual number of working days	Before	After
		Time of cumulative workloads (Second)	Time of cumulative workloads (Second)
A	8	6,996	6,523
B	18	11,068	9,198
C	18	31,001	9,895
D	11	15,786	11,251
E	3	1,671	3,212
D	21	19,122	10,016
G	16	14,228	10,064
H	12	8,957	10,017
I	12	9,350	9,938

J	13	8,386	9,360
K	6	4,147	10,376
L	11	10,750	9,913
M	5	1,166	9,383
N	7	3,771	8,767
O	5	3,520	7,659
P	4	1,642	9,382
Q	4	2,665	9,264
Mean		9,072	9,072
SD		7,754	1,847

Source: Authors, (2024).

Note: In the section about some attendants having different cumulative workload values than other attendants, this is due to the fact that in that month, those specific attendants had fewer actual working days compared to other attendants.

The empirical findings suggest that the implementation of the straightforward program for task assignments has a substantial influence on reducing the variance in cumulative workloads. The statistical significance of this impact is robust, attaining a 95% confidence level. Additionally, the p-value derived from the F-test, being less than 0.05, leads to the rejection of the null hypothesis (H0: $\sigma_1 = \sigma_2$) and the acceptance of the alternative hypothesis (H*1*: $\sigma_1 > \sigma_2$). This implies that the program significantly contributes to minimizing the variability in cumulative workloads, fostering a more consistent distribution among the hospital transport staff.

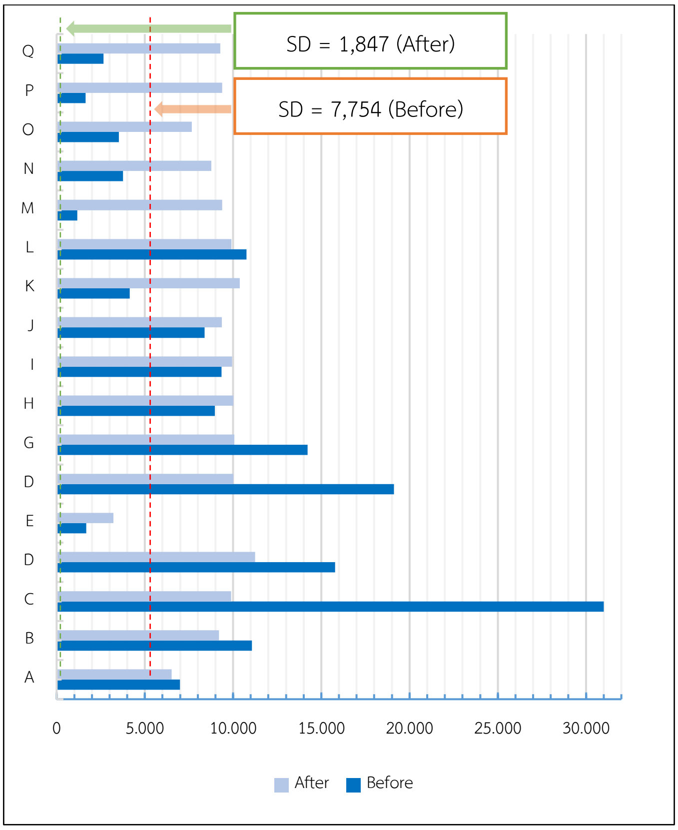

Figure 3: Comparison graph of workload results before and after optimization.
Source: Authors, (2024).

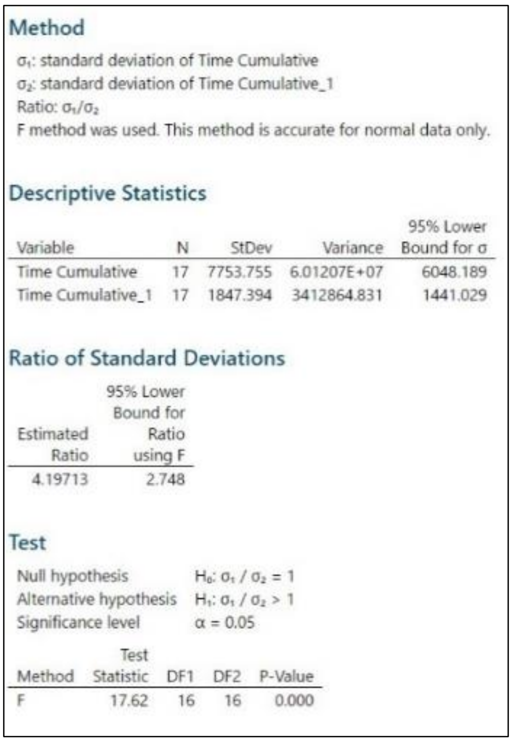

Figure 4: Statistical Analysis using F-Test.
Source: Authors, (2024).

Table 3: Summary of user satisfaction evaluation for the program.

Satisfaction Aspect	Satisfaction	
	Mean Score	**Percentage**
1. Operational Processes / Program Workflow	4.5	90
1.1 Program Workflow Pattern	4	80
1.2 Program Task Execution Capability	5	100
2. Program Efficiency	3.6	72
2.1 Accuracy and Precision	4	80
2.2 Alignment with Objectives	3	60
2.3 Data Accuracy and Currency	4	80
2.4 User-Friendliness	4	80
2.5 Program Stability	3	60
3. User-Friendliness	3	60
3.1 Overall Program Design Suitability	3	60
3.2 Ease of Use and Simplicity	3	60
4. Program Quality	4	80

4.1 Future Usability of the Program	4	80
4.2 Satisfaction with Program Usage	4	80
Overall Score	3.78	75.6

Source: Authors, (2024).

Note:
Mean satisfaction scores interpretation:
4.51 - 5.00: Highly Satisfied
3.51 - 4.50: Satisfied
2.51 - 3.50: Moderate Satisfaction
1.51 - 2.50: Dissatisfied
1.00 - 1.50: Highly Dissatisfied
Satisfaction percentage interpretation:
91 - 100%: Highly Satisfied
71 - 90%: Satisfied
51 - 70%: Moderate Satisfaction
31 - 50%: Dissatisfied
21 - 30%: Highly Dissatisfied

The empirical findings in Figure 4 suggest that the implementation of the straightforward program for task assignments has a substantial influence on reducing the variance in cumulative workloads. The statistical significance of this impact is robust, attaining a 95% confidence level. Additionally, the p-value derived from the F-test, being less than 0.05, leads to the rejection of the null hypothesis (H0: $\sigma_1 = \sigma_2$) and the acceptance of the alternative hypothesis (H_1: $\sigma_1 > \sigma_2$). This implies that the program significantly contributes to minimizing the variability in cumulative workloads, fostering a more consistent distribution among the hospital transport staff.

In conclusion, the application of the program for task assignments has demonstrated not only practical efficacy but also statistical significance, affirming its positive influence on mitigating the variability in cumulative workloads for hospital transport staff at the case study hospital.

Following the statistical analysis using the F-Test with Minitab software, the examination of the standard deviations of cumulative workloads for hospital transport staff, both assigned tasks using the traditional method and the newly introduced program, revealed a statistically significant reduction in workload variance. The ensuing standard deviation values were then utilized to calculate the proportional reduction in workload variance before and after the implementation of the program, with the comprehensive findings meticulously compiled into a thorough report.

Additionally, the program, meticulously crafted by the researcher, was presented to the head of the transport center for practical application. The opportunity for hands-on usage allowed the center's head to gain profound insights into the intricacies of the program's operational processes. A detailed evaluation form was subsequently administered, focusing on four key dimensions: 1) Process or operational workflow, 2) Program efficiency, 3) User-friendliness, and 4) Program quality.

The culmination of the evaluation process yielded an overall satisfaction level with a mean score of 3.78, indicating a commendable degree of contentment. Notably, the assessment of operational processes (Dimension 1) stood out with the highest satisfaction level, attaining a mean score of 4.5. Simultaneously, program efficiency (Dimension 2) garnered a satisfactory mean score of 3.6. User-friendliness (Dimension 3) achieved a moderate satisfaction level, obtaining a mean score of 3, while program quality (Dimension 4) secured a high satisfaction level with a mean score of 4. The nuanced satisfaction ratings are meticulously detailed in Table 3**.**

IV.6 MANAGERIAL INSIGHTS

The managerial insights derived from this research provide valuable information and recommendations for decision-makers and managers. Here are some key managerial insights:

1. Efficiency Improvement through Program Implementation: The implementation of the program has resulted in increased operational efficiency. The program's task execution capability and workflow pattern received high satisfaction scores (100% and 80%, respectively). Managers can infer that adopting this program enhances overall efficiency in task management.

2. Accuracy and Data Quality: Users expressed satisfaction with the program's accuracy and precision, data accuracy, and currency (80% satisfaction for each). This suggests that the program contributes to maintaining high data quality. Managers should recognize the importance of accurate information for decision-making processes.

3. User-Friendly Design: The program's overall design suitability and ease of use received moderate satisfaction scores (60%). Managers should consider investing in further user interface enhancements to make the program more user-friendly, potentially leading to increased satisfaction and productivity.

4. Stability and Future Usability: Program stability received a satisfaction score of 60%, indicating room for improvement. Managers should focus on enhancing the stability of the program to ensure a seamless user experience. Additionally, the positive response regarding the future usability of the program (80%) suggests that continued investment in the program is worthwhile.

5. Holistic Program Quality: The overall program quality, including its ability to meet objectives and user satisfaction, scored 80%. Managers can interpret this as a positive indication that the program is perceived as valuable and meets the needs of the users. Continuous quality monitoring and updates should be implemented to sustain high satisfaction levels.

6. Employee Training and Support: To address areas of lower satisfaction, particularly in user-friendliness, managers should consider implementing training programs or providing additional support to users. This can help users adapt to the program more easily and increase overall satisfaction.

7. Strategic Decision-Making: The insights gained from the research can inform strategic decision-making regarding the use and enhancement of the program. Whether it involves refining the user interface, improving stability, or planning for the program's future use, managers can strategically allocate resources for maximum impact.

8. Continuous Feedback Loop: Establishing a continuous feedback loop with end-users can further enhance the program's effectiveness. Regularly soliciting feedback, addressing concerns, and implementing user-driven improvements contribute to long-term user satisfaction and sustained program success.

By considering these insights, managers can make informed decisions to optimize the use of the program, improve user satisfaction, and align organizational processes with strategic objectives.

V. CONCLUSIONS

The researcher has embarked on the systematic aggregation of data, encompassing information derived from the work logging software employed by the transport staff. This dataset is instrumental in the derivation of speed parameters for the equipment integral to patient transport, both in terms of primary conveyance apparatus and ancillary devices. Furthermore, pertinent data concerning inter-departmental distances is compiled to facilitate the computation of workload metrics. Subsequently, a mathematical model is conceived, characterized by the optimization of the objective function—specifically, the minimization of the absolute deviation in cumulative workload values across each month, as articulated in Equation (4). The ensuing imperative is the meticulous validation of the mathematical model's precision, a task undertaken through the simulation of petite-scale data using the Excel Solver functionality within the Microsoft Excel milieu. The outcomes of this simulation attest to the model's efficacy in task assignment, demonstrating a predilection for staff members with reduced cumulative workloads, thus aligning seamlessly with the stipulated research objectives.

Post-validation, the research trajectory pivots towards the development of a rudimentary program. This choice leans towards Microsoft Excel due to its adeptness in accommodating Visual Basic for Applications (VBA) code amalgamated into the fabric of Visual Basic applications within the Microsoft Excel ecosystem. The program's elementary nature engenders an automatic generation of results predicated on assigned tasks, leveraging the underlying mathematical model. A trial deployment of the program ensues, utilizing authentic work data from the transport staff in September, juxtaposing the outcomes against the actual task assignments. This comparative analysis reveals a noteworthy reduction in the standard deviation of the cumulative workload for transport staff—from 7,754 seconds to 1,847 seconds—constituting a consequential diminution of 76.17%.

In the vein of suggestions for augmentative refinement, it is posited that the program could be elevated through the infusion of code in alternative languages, thereby concomitantly enhancing processing velocity and broadening the gamut of tasks within its purview [13]. Anticipating scenarios involving the engagement of temporary staff, prospective iterations may contemplate the integration of additional conditions to accord precedence to the task allocation for daily wage laborers. Instances where transport staff undergoes transient work cessation and subsequent resumption would necessitate programmatic adjustments to forestall the imposition of unduly burdensome tasks upon returning staff members. Moreover, a prudent course of action entails the delineation of an upper limit for the workload value, preempting the assignment of tasks that surpass manageable thresholds.

Further considerations advocate for program refinements catering to scenarios typified by consecutive or overlapping task assignments. A nuanced modification would entail the incorporation of supplementary conditions stipulating that actively engaged transport staff should be exempted from the reception of new tasks. This adaptive measure ensures that the program mitigates the challenge of consecutively or concurrently assigned tasks. Additionally, programmatic adaptations beckon the integration of functionalities permitting nursing personnel to input data into the system. This symbiotic interfacing allows the mathematical model ingrained in the system to systematically process information and proactively apprise the transport center regarding new tasks, subsequently allotting these tasks to available transport staff.

Moreover, this research can provide actionable insights that can be applied to SME, enabling enhanced operational efficiency, resource optimization, and overall competitiveness through the adaptation of workload balancing and mathematical modeling principles.

VI. AUTHOR’S CONTRIBUTION

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