한국항해항만학회지 제43권 제5호
J. Navig. Port Res. Vol. 43, No. 5 : 273-280, October 2019 (ISSN:1598-5725(Print)/ISSN:2093-8470(Online))
DOI : http://dx.doi.org/10.5394/KINPR.2019.43.5.273

A Cruise Ship Itinerary Planning Model for Passenger Satisfaction

† *Seong-Cheol Cho*

† *Division of Shipping Management, Korea Maritime and Ocean University, Busan 49112, Republic of Korea*

Abstract : *This study developed an optimization model, defined as the IPS (Itinerary for Passenger Satisfaction), for a cruise ship to identify an itinerary that maximizes passenger satisfaction. A 0-1 integer programming model was developed to provide an optimal sequence of ports of call, assigning a destination to each day of the cruise. The concepts of the destination access network and the neighborhood of a destination were designed and manipulated to organize the complex network of destinations so that each next destination is selected within a practical overnight sail. The developed model can also be viewed as a reduced variant of the traveling salesperson problem with less constraints. A set of example tests shows that practical scenarios of the IPS with moderate cruise duration can be easily solved with light computation loads. Considering cruise ship passengers usually make their decisions not relying on only one destination but on an itinerary in its entirety, the purpose of this study was to identify itinerary alternatives to attract potential cruise passengers for attaining maximum occupancy level.*

Key words : *Cruise Operation, Itinerary Planning, Network, Integer Programming, Passenger Satisfaction*

1. Introduction

Though the cruise industry yet accounts for a limited portion in both the world tourism and world shipping markets, its fast growing of the annual growth rate over 6.5% during the last three decades(Cruise Market Watch, 2019) has gradually motivated many recent studies related to cruise operations. Sun et al.(2011) provided one of the early reviews on the emerging studies and research issues on cruise revenue management including itinerary planning. Recently, Cho and Zhang(2017) developed a simple pricing policy for cruise revenue management based on real time reservation updates. Reflecting the recent dominant position of China in the Asian cruise market(Sun et al., 2014), Hung et al.(2019) have provided a unique comprehensive survey comparing the cruise related studies written in Chinese with those written in English. A distinguished conceptual synthesis of cruise management perspectives has been provided by Papathanassis(2017), who has summarized and integrated the evolving concepts of cruise and its key management issues especially focusing on the growing trend of e-Cruise technologies. Despite the increasing research works, it should be emphasized that many important cruise management issues are in need of more reliable analytic methods(Hung et al., 2019; Wang et al., 2016).

The cruise itinerary planning is one of the essential decision-making problems requiring reliable analytic methods for cruise operations. The first pioneering study was attempted by Hersh and Ladany(1989), who adopted regression analysis and dynamic programming to suggest an optimal itinerary. Cho et al.(2012) developed an integer programming model, based on a synthesizing network of candidate itineraries, to provide optimal itinerary planning in a long term perspective. Recently, Wang et al.(2016) proposed a conceptual itinerary planning model, defined as the itinerary schedule design(ISD), to minimize fuel cost and maximize passenger utility, but with no specific formulation. Another study on itinerary planning, with a detailed formulation, has been provided by Asta et al.(2018) to maximize profit and passenger satisfaction combined. Since the monetary profit and the passenger satisfaction cannot share a common unit of measure, they actually have attempted a compromise between the two heterogeneous units by using some intuitive weights.

This study develops an optimization model, defined as the IPS(Itinerary for Passenger Satisfaction), for cruise itinerary planning with the cruise duration fixed. Different from the above mentioned recent studies referring to passenger satisfaction, this study focuses on maximizing purely the passenger satisfaction without combining it with other heterogeneous financial values such as profit or cost. This has made the IPS differentiated from the previous itinerary planning models, and intuitively clearer for real

† Corresponding author, cho@kmou.ac.kr 051)410-4386

implementation. The IPS also appears to have a computational advantage over the recently developed itinerary optimization models(Mancini and Stecca, 2018; Asta et al., 2018), which often exceed tolerable computations of standard optimal solution methods and require heuristics even for solving instances of ordinary size. The binary integer programming model developed for the IPS in this study is found to generate an optimal sequence of ports of call with light computations for instances of practical size. This computational advantage also facilitates repeated applications of the IPS as tested and suggested in this study.

A network structure among the candidate destinations, defined as the destination access network(DAN), is associated with the IPS. As a combinatorial optimization problem, the IPS turns out to be a reduced variant of the traditional traveling salesman problem(TSP, Nehmhauser and Wolsey, 1988), and an optimal itinerary appears as a closed path on DAN. The developed model has been tested with a set of different satisfaction values artificially assigned to each destination. The tested instances are made to have practical cruise duration fit for the current mass market section of contemporary cruises. Since cruisers usually make their decisions not on a single destination but on an itinerary as a whole(Sigala, 2017; Rodrigue and Notteboom, 2013), and the itineraries significantly affect the occupancy rate(Lee and Ramdeen, 2013), the IPS is intended to provide an itinerary alternative for reaching and sustaining maximum occupancy.

The next section develops the model with its assumptions and important preliminary concepts. Section 3 shows a set of model tests to illustrate how the IPS will work in practice. Section 4 summarizes the study discussing future research possibilities. A remark is also added to elaborate the practical merit of extensive application capacity identified with the IPS formulation beyond the cruise itinerary planning.

2. Itinerary for passenger satisfaction

There are three levels of itinerary planning for cruise operation(Asta et al., 2018) depending on the planning period: long term, medium term, and day by day plannings. This study concerns a day by day itinerary, which determines a sequence of daily ports of call with a fixed cruise length.

The cruise length of m, in this study, means that the cruise is planning to visit exactly m different destinations, one per day during the cruise, and so represents a $m+1$ night (or $m+2$ day) cruise in practice. The cruise ship departs from a home port on day 0, and visits successively m different destinations, one port of call each day during the cruise travel, and finally returns to the home port. The IPS aims to find an optimal sequence of ports of call among all possible mixes to maximize the passenger satisfaction perceived from visiting all the destinations. The mathematical formulation of the IPS is developed to be a 0-1 integer program.

2.1 Destination access network

Different sailing speeds lead to different fuel costs and have been considered as decision-making variables in some studies to optimize tramp ship operations(Norstad et al., 2011; Wen et al., 2016). A recent optimization model(Mancini and Stecca, 2018) developed for cruise itinerary planning also included the travel speed as a discrete decision variable, but turned out to exceed the reasonable computation capacity of analytic solution methods to find optimal itineraries for many practical instances. This study focuses on maximizing passenger satisfaction instead of financial values, and supposes that a proper navigation speed is predetermined by analyzing past fuel consumptions and customer responses.

Once a proper navigation speed is determined, the sailing time between any pair of candidate destinations can be easily computed. All these computations lead to a connection structure among candidate destinations defined, in this study, as the destination access network(DAN). When a cruise itinerary planning involves n candidate destinations, it is associated with a DAN having a set nodes $N=\{0,1,\cdots,n\}$ and a set of arcs A. Node 0 represents the home port, and node j a candidate destination($j(\in\{1,\cdots,n\})$. A is the set of undirected arcs $\{i,j\}$ indicating that node $i(j)$ is accessible by an overnight sail from node $j(i)$.

Since any pair of nodes accessible from each other within an overnight sail at a certain speed are also accessible at any higher speed, it is clear that the number of arcs in DAN will increase as sailing speed increases. DAN is also different from traditional network models, which usually have numbers associated with each arc. Instead of arcs, DAN has numbers, s_j, associated with each node $j(=1,\cdots,n)$, and they represent the satisfaction values estimated for each candidate destination. **Fig. 1** shows an example of a DAN with three($n=3$) candidate destinations.

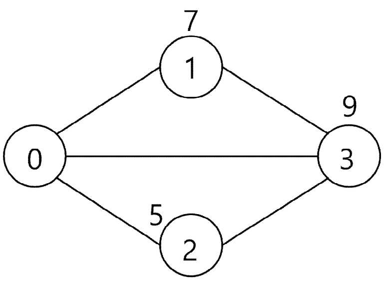

Fig. 1 DAN with $n=3$

An IPS instance with its associated DAN is a combinatorial optimization problem to find a directed closed path expressed as $p=(0,i_1,\cdots,i_m,0)$, which allows no repetition among the intermediate nodes and maximizes the sum of satisfaction values($\sum_{k=1}^{m} s_{i_k}$). The closed path $(0,2,3,0)$ in **Fig. 1**, shows an itinerary option for a 3 night $(m=2)$ cruise with 3 candidate destinations. The passenger satisfaction of this itinerary is $14(=5+9)$, which is the sum of the satisfaction values associated with the destinations 2 and 3.

Since each itinerary corresponds to a closed path on a DAN, the IPS can be viewed as a variant of the traditional TSP. The closed paths, however, do not have to visit all the n nodes as in the TSP, but only part of them(exactly m nodes). In this sense, the IPS is a restricted variant of the TSP with less complexity and computation than the original TSP. It also should be mentioned that the IPS, different from the TSP, is not always feasible. For an example, if the arc $\{0,3\}$ is deleted out from the DAN in **Fig. 1**, it is clear that the revised DAN now turns out to have no closed path having m(=2) intermediate nodes.

Though the IPS is a smaller variant of the TSP, it should be worth noting that finding an optimal itinerary by total enumeration could require exponentially increasing computations as m increases. **Theorem 1** proves this exponential property.

Theorem 1. Let's suppose $m \geq 2$, and $n \geq m+1$. Let $p^*=(0,i_1^*,\cdots,i_m^*,0)$ be an optimal itinerary of an IPS instance. Let's suppose also that all the other optimal itineraries have the same set of intermediate nodes as p^*. Then, the maximum number of non-optimal itineraries is no less than 2^m.

(Proof) It is clear that any closed path having the same intermediate nodes as p^*, starting from and returning to node 0, is also optimal, since it has the same sum($\sum_{k=1}^{m} s_{i_k^*}$) of satisfaction values as p^*. This implies that the possible maximum number of optimal itineraries is $m!$, which is the number of all possible permutations of m distinct elements in $\{i_1^*,\cdots,i_m^*\}$. The possible maximum number of itineraries is the number of all possible permutations arranging m entities among n, and so equal to $n(n-1)\cdots(n-(m-1))$. From $n \geq m+1$ follows $n-(m-1) \geq 2$, and this immediately leads to $n(n-1)\cdots(n-(m-1)) \geq (m+1)!$. All these imply that the maximum number of itineraries except the optimal is no less than $(m+1)!-m!$. Since $(m+1)!-m! = m!((m+1)-1) = (m!)m$ and $m \geq 2$, it follows that $(m!)m \geq (2^{m-1})2 = 2^m$, which completes the proof.

An important sub-structure of DAN used to develop the mathematical formulation for the IPS is the neighborhood of a node, $N(i)$, defined for each $i \in N$. It is the set of nodes, in $N-\{0\}$, adjacent to node i. This indicates that any node j in $N(i)$ is accessible by an overnight sail from node i and vice versa. It is easy to find that $N(0)=\{1,2,3\}$, $N(1)=N(2)=\{3\}$, and $N(3)=\{1,2\}$ in **Fig. 1**.

2.2 Assumptions and symbols

The cruises, in this study, are composed of shore excursions each daytime at different destinations, and overnight sails bound for the next destinations. Since luxury lines often offer to stay at major destinations more than one day, the one day stay at a port of call is more likely associated with the contemporary cruises accounting for a major market of the current world cruises. The destination mix in an itinerary should be one balancing old and new, familiarity and uncertainty, consistency and novelty(Sigala, 2017), and full and half day shore excursions chosen among candidate destinations.

It is assumed that $m \geq 2$ to eliminate trivial itinerary planning instances. In fact, if $m=1$, the optimal itinerary is nothing but to visit the one single destination that has the maximum satisfaction value. It is also assumed that $n \geq m+1$, which reflects a real decision-making situation where the cruise can practically decide to select a different destination each day among multiple candidates competing with one another to attract more cruise tourists.

The objective of the IPS is to maximize the total passenger satisfaction perceived from all the destinations included in the itinerary. Customer satisfaction in service businesses, in general, enhances customer loyalty, which drives growing customers' repeat purchase and finally leads to growing profitability(Fitzsimmons et al., 2014). It is also found in cruise tourism services that the itinerary planning significantly affects the occupancy rates of cruises(Lee and Ramdeen, 2013) through increasing passenger satisfaction(Sigala, 2017; Gibson, 2013). These findings imply that high customer satisfaction with itineraries is an essential basis for the cruise service to reach and maintain high occupancy by attracting potential passengers. Maintaining high occupancy rates is also a sound prerequisite for economically sustainable cruise operations in practice, since they usually depend on heavy fixed costs(Vogel, 2017) related with the ship capacity itself while variable costs usually account for a small limited portion.

The model uses the following symbols for variables and data.

1) $C=\{1,\cdots,n\}=N-\{0\}$: Set of candidate destinations.
2) $N(i)$: Neighborhood of i. ($\forall i\in N$)
3) s_j: Satisfaction value of candidate destination j. ($\forall j\in C$)
4) x_{kj}: Binary variables to indicate whether the destination j is to be visited on day k, which takes 1 if visited, and 0 otherwise. ($\forall k=1,\ \cdots,\ m$ and $j\in C$)

The mathematical formulation of the IPS is detailed in the next subsection.

2.3 Itinerary planning model

The satisfaction value(s_j) associated with each candidate destination can usually be measured based on passenger response surveys or opinions from past cruise experiences(Asta, 2018). Such destination evaluations as Tourist Area Life Cyle, Doxey's irredex(irritation index), destination amalgam(Gibson, 2012), or online rankings of potential destinations worldwide(Euromonitor International, 2018) can also be adopted. Wang et al.(2014) have suggested a ranking of important destinations based on the factor analysis and the analytic hierarchy process(AHP). Options of half day or full day stays can also be assigned to each destination to adjust the satisfaction values regarding shore excursions. Since different evaluation approaches reflect different perspectives on destinations, no single method works best for all cruises. A timely evaluation method, in practice, could be chosen and tweaked to best integrate various up-to-date aspects of destinations and different perspectives(Asta et al., 2018). It also should be noted that different evaluations reflecting different perspectives can be easily compared with one another by repeated applications of the IPS as is suggested from the tested examples of this study.

The objective function of the IPS is presented in (1), and the constraints for itineraries to satisfy, while maximizing the objective function, are specified as in (2)-(7).

$$\text{(IPS)}\quad \text{Maximize } s=\sum_{j=1}^{n}\sum_{k=1}^{m}s_j x_{kj} \tag{1}$$

Subject to

$$\sum_{j\in N(0)} x_{1j}=1 \tag{2}$$

$$\sum_{j\in N(0)} x_{mj}=1 \tag{3}$$

$$\sum_{j\in N(i)} x_{kj}\ge x_{k-1\ i} \qquad \forall k=2,\ \cdots,m,\ \forall i\in C \tag{4}$$

$$\sum_{i=k}^{m} x_{kj}\le 1 \qquad \forall j\in C \tag{5}$$

$$\sum_{j\in C} x_{kj}=1 \qquad \forall k=1,\ \cdots,m \tag{6}$$

$$x_{kj}\in\{0,1\}\quad \forall k=1,\cdots,\ m \text{ and } j\in C \tag{7}$$

Since $\sum_{k=1}^{m}x_{kj}$ indicates whether the candidate destination $j\,(\in C)$ is to be visited ($\sum_{i=1}^{m}x_{kj}=1$) or not($\sum_{k=1}^{m}x_{kj}=0$), the function $s=\sum_{j=1}^{n}\sum_{k=1}^{m}s_j x_{kj}$ in (1) exactly computes the total sum of satisfaction values of the destinations included in a feasible itinerary. Therefore, the IPS with the objective function of (1) seeks to find an optimal itinerary planning, which provides the maximum value of overall passenger satisfaction associated with all the destinations.

Constraints (2) and (3) imply that the first and the last destinations of the cruise ought to be selected exactly among those in the neighborhood of the home port. The constraints (6) ensure that exactly one destination be visited on each cruise day, while constraints (5) allow no repeated visits. The constraints (4) are neighborhood constraints and regulate each next port of call to be selected only in the corresponding neighborhood. The last set of constraints in (7) simply state that all the variables are 0-1 integer variables.

Any IPS instance of (1)-(7), with cruise length m and n candidate destinations, has mn binary variables, and two constraints from (2)-(3), $(m-1)n$ from (4), n from (5), m from (6), and $m(n+1)+2$ constraints in total. Any instance of typical 7 day cruises($m=5$) with 10 candidate destinations($n=10$) is formulated to have 50 binary variables and 57 constraints.

Though the IPS can be seen as a variant of the TSP, it should be noted that the required number of constraints for formulating the IPS is, in fact, much less than the exponential one(Nemhauser and Wolsey, 1988) found in the integer programming formulation of the TSP. However, the exponential property proved in **Theorem 1** implies that it may be hard beyond reasonable computational burdens to find optimal itineraries for exceptionally large instances of the IPS.

3. Numerical examples and implications

The satisfaction values may vary over time due to various changes in weathers, attractions and annual events at destinations, responses from the host community, or political tensions, etc. Different assessments of those values can also suggest different itinerary alternatives. This section presents two examples, which involve different satisfaction values artificially assigned to each candidate destination. The example tests illustrate how the IPS will work to develop optimal itineraries in practice.

3.1 Example with $m=2$ and $n=3$

The first example represents a 4 day cruise embarking (on day 0) and disembarking (on day 3) at the same home port, and visiting 2 destinations during the travel. **Fig. 1** is supposed to be the DAN associated with this IPS instance. It is intuitively clear, even without the need of any analytic model, that $(0,1,3,0)$ and $(0,3,1,0)$ are both the optimal itineraries producing the maximum passenger satisfaction of $16(=7+9)$. The passenger satisfaction from visiting destinations 1 and 3 successively is greater than visiting 2 and 3 by $2(16-14)$. In case of a different evaluation of satisfaction values, probably in a different cruise season, assigning 6 to node 1, and 7 to node 2, the optimal itinerary is now altered to $(0,2,3,0)$ (or equivalently $(0,3,2,0)$).

The integer programming formulation of the IPS instance with **Fig. 1** appears as follows.

$$\text{Maximize } s=7x_{11}+7x_{21}+5x_{12}+5x_{22}+9x_{13}+9x_{23} \tag{1}$$

Subject to

$$x_{11}+x_{12}+x_{13}=1 \tag{2}$$

$$x_{21}+x_{22}+x_{23}=1 \tag{3}$$

$$\begin{aligned} x_{23} &\geq x_{11} \\ x_{23} &\geq x_{12} \\ x_{21}+x_{22} &\geq x_{13} \end{aligned} \tag{4}$$

$$\begin{aligned} x_{11}+x_{21} &\leq 1 \\ x_{12}+x_{22} &\leq 1 \\ x_{13}+x_{23} &\leq 1 \end{aligned} \tag{5}$$

$$x_{kj} \in \{0,1\} \quad \forall k=1,2 \text{ and } j=1,2,3 \tag{7}$$

This simple example actually does not need constraints of (6), since they happen to be the same as (2)-(3).

An optimal solution of $x^*_{11}=x^*_{23}=1$ (and $x^*_{kj}=0$, for the rest) has been found instantly by solving this instance with the *Solver* module installed in *MS Excel 2016*. The optimal solution suggests the itinerary visiting destination 1 as its first port of call ($k=1$), and destination 3 the next day ($k=2(=m)$).

3.2 Example with $m=4$ and $n=8$

The following example with $m=4$ and $n=8$ represents a 6 day cruise visiting 4 different ports of call among 8 candidates. This IPS instance requires $32(=4\times 8)$ binary variables and $38(=4(8+1)+2)$ constraints for its integer programming formulation. The model data associated with 8 candidate destinations are summarized in **Table 1**. The home port has its own neighborhood destinations of 1, 2, 3, and 7, i.e. $N(0)=\{1,2,3,7\}$. The satisfaction values are estimated by the cruise line to have standardized scores between 0 and 10.

Table 1 Data for IPS

Destination	Satisfaction value	Neighborhood
1	9.0	3
2	4.7	3, 4
3	5.8	1, 2, 5, 6
4	6.4	2, 5, 6
5	7.0	3, 4, 7, 8
6	5.7	3, 4, 8
7	8.3	5, 8
8	7.7	5, 6, 7

Again, **Table 1** leads to the construction of the DAN as in **Fig. 2**. The DAN has 15 arcs, much less than the possible maximum number of arcs of $\frac{9!}{2!(9-2)!}=36$. This limited number of arcs is due to the reduction that DAN is always constructed only to contain those arcs, which have the adjacent nodes accessible from each other by an overnight sail. If the sailing speed is readjusted to a higher level, then it will come up with a revised DAN having more arcs than in **Fig. 2**.

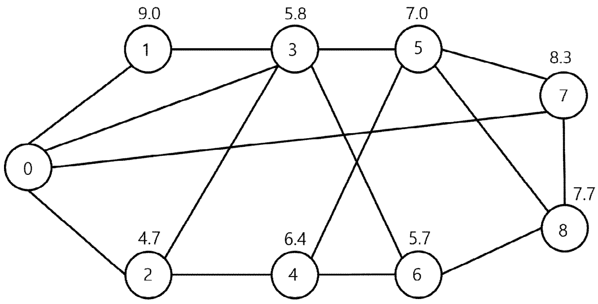

Fig. 2 DAN with $n=8$

Though its complete presentation (with 32 variables and 38 constraints) would be too lengthy to be included here, the integer programming formulation of this IPS instance appears briefly as follows.

$$\text{Maximize } s=9\sum_{k=1}^{4}x_{k1}+4.7\sum_{k=1}^{4}x_{k2}\cdots+7.7\sum_{k=1}^{4}x_{k8} \tag{1}$$

Subject to

$$x_{11}+x_{12}+x_{13}+x_{17}=1 \tag{2}$$

$$x_{41}+x_{42}+x_{43}+x_{47}=1 \tag{3}$$

$$\begin{aligned} x_{23} &\geq x_{11} \\ x_{23}+x_{24} &\geq x_{12} \\ &\cdots \\ &\cdots \\ x_{45}+x_{48} &\geq x_{37} \\ x_{45}+x_{46}+x_{47} &\geq x_{38} \end{aligned} \tag{4}$$

$$\begin{aligned} &\sum_{k=1}^{4}x_{k1}\leq 1 \\ &\cdots \\ &\sum_{k=1}^{4}x_{k8}\leq 1 \end{aligned} \tag{5}$$

$$\begin{aligned} &\sum_{j=1}^{8}x_{1j}=1 \\ &\cdots \\ &\sum_{j=1}^{8}x_{4j}=1 \end{aligned} \tag{6}$$

$$x_{kj}\in\{0,1\} \quad \forall k=1,\cdots,4 \text{ and } j=1,\cdots,8 \tag{7}$$

The *Solver* in *MS Excel 2016* has instantly found an optimal solution of $x_{11}^{*}=1, x_{23}^{*}=1, x_{35}^{*}=1, x_{47}^{*}=1$ (and $x_{kj}^{*}=0$ for the rest), which provides the maximum passenger satisfaction of $30.1(=9+5.8+7+8.3)$. The itinerary suggested by the optimal solution is summarized in **Table 2**.

Table 2 Optimal itinerary with $m=4$, $n=8$

Day	Port of call
0	Embarking at home port
1	Destination 1
2	Destination 3
3	Destination 5
4	Destination 7
5	Disembarking at home port

As a directed closed path of $(0,1,3,5,7,0)$ on the associated DAN, the optimal itinerary appears as in **Fig. 3**.

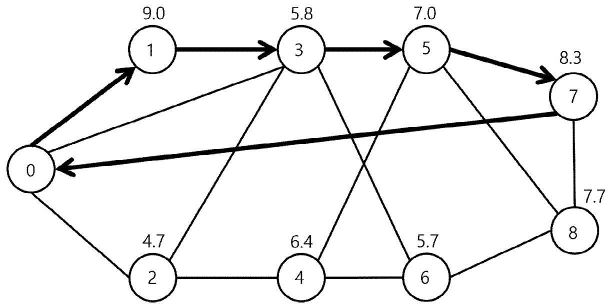

Fig. 3 Optimal Itinerary on DAN with $m=4, n=8$

Since different evaluations on the same destinations are expected to provide different optimal itineraries, three more IPS instances with different satisfaction values are tested. Each reevaluated instance is made to have exactly two different satisfaction values from the original one. The optimal itineraries for each of the four different evaluations including the original one(the first column) are found as in **Table 3**, where s^{*} indicates each corresponding maximum passenger satisfaction.

Table 3 Optimal itineraries with different evaluations

Destination	Satisfaction value			
1	9.0	4.7	9.0	9.0
2	4.7	9.0	4.7	4.7
3	5.8	5.8	6.4	5.8
4	6.4	6.4	5.8	6.4
5	7.0	7.0	7.0	5.7
6	5.7	5.7	5.7	7.0
7	8.3	8.3	8.3	8.3
8	7.7	7.7	7.7	7.7
Optimal itinerary	(0, 1, 3, 5, 7,0)	(0,7,5, 4,2,0)	(0,7,5, 3,1,0)	(0,1,3, 5,7,0)
s^*	30.1	30.7	30.7	28.8

It should also be noted that the first and the fourth evaluations happen to produce the same itinerary, but with different passenger satisfactions.

The examples tested in this section illustrate how the developed IPS will work, in practice, for obtaining optimal itineraries. Though the computational burdens to solve exceptionally large instances may increase as proved in **Theorem 1**, major cruise instances of moderate duration are expected to be easily formulated and solved as observed from the tested examples. This moderate computation load also alludes to a potential advantage of repeat use of the IPS until finally selecting and posting one of the optimal itineraries to the market. The final selection could benefit from comparing different alternatives, which reflect different perspectives on the same set of destinations.

4. Conclusions

This study has developed an itinerary planning model defined as the IPS using 0-1 integer programming to maximize passenger satisfaction. By maximizing the passenger satisfaction instead of optimizing financial values of profit or cost, this study is differentiated from the previous studies on itinerary planning optimization, and appears unique of this kind. The IPS provides an optimal sequence of ports of call to maximize the total sum of satisfaction values associated with each destination. The IPS, with its associated DAN, is viewed as a reduced variant of the TSP with less complexity in both formulation and computation. Despite the less complexity, the existence of possible exponentially growing computations for exceptionally large instances of the IPS is also proved.

The examples tested with two major cruise lengths show that the IPS will work well with a light load of computation for practical instances with moderate cruise duration. The IPS is developed aiming at effectively providing an itinerary alternative to reach and sustain maximum occupancy. Remaining at the maximum occupancy level is a crucial goal for economically sustainable cruise businesses in general, since they usually operate under a dominant burden of fixed cost mostly determined by the cruise ship capacity itself. Considering the moderate computations expected of practical instances, a repeat implementation of the IPS is recommended to improve the quality of the final choice among many optimal itineraries generated from different destination evaluations.

Though the IPS supposes the typical cruise returning to its home port, the model can be easily extended to cover other cruises with origins different from their final ports of call. It can be done by simply replacing $N(0)$ in the constraint of (3) with the neighborhood of the final port of disembarkation. This kind of cruise is frequently observed, in fact, when a cruise ship is to move to a new home port for a strategic repositioning.

Since passengers sometimes prefer to stay at a satisfying destination longer than one day(Marti, 1990; Sigala, 2017), the extension of the IPS to include variable stays is a possible future research work. This extension would require more complexities in both formulation and computation. Implementing the IPS for real cruise operations is also one of the future research subjects of practical worth. It would provide real world observations for showing how the IPS could work to improve the cruise occupancy level through increasing the passenger satisfaction.

As a final remark, it should be added that the IPS can be, in fact, applied to a broader range of traveling decisions beyond the cruise itinerary. The mathematical formulation of the IPS can be reasonably applied to any decision-making circumstances, where the decision maker would visit a fixed number of places successively before returning to the origin to maximize the total benefits accruing from each place. This extensive application capacity also underpins future studies to find more refined analytic results on the IPS as a multi-purpose optimization model.

Acknowledgements

This study was supported by the visiting research year program of Korea Maritime and Ocean University.

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Received 22 August 2019
Revised 5 September 2019
Accepted 20 September 2019