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A Note on Runway Capacity Definition and Safety

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ABSTRACT

The following is a discussion on the different aspects of the term *capacity* as well as a brief look at the commonly used capacity definitions in industrial and operations engineering in general and in Civil Aviation in particular. We maintain that quality factors (including more specifically here, safety) must be explicitly considered in runway capacity definition, and accordingly, we provide a revision on previous perspectives.

Keywords: Capacity; Air transportation; Runway; Safety.

1. INTRODUCTION

According to the Airports Console International (ACI, 2010) more than 1.6 billion passenger traffic (total passengers enplaned and deplaned, passengers in transit counted once) and 1.4 million traffic movement (total movements: landing + take off of an aircraft, including both passenger and cargo aircraft) were handled by the 30 busiest airports around the globe in 2010. Furthermore, the increasingly high demand for the runway arrival and departure slots in congested airports around the world and the expense of investing on new runways have made them very limiting and highly valuable resources of air transportation networks.

These facts, among others,underscore the high impact of studies concerning capacity, safety and efficiency evaluations in air transport system components especially regarding the runways as the system bottlenecks. These studies can be practically helpful only when we have a scientifically suitable and comprehensive definition for the capacity term. In this note we aim to discuss commonly usedairport and runway capacity definitions, some of their shortcomingsand then introduce a revised definition.

2. CAPACITY DEFINITION

Capacity is the significant feature of economic facilities producing goods or services, and must be properly estimated as it is essential in operations planning and control (i.e., in timing and scheduling). In the Aviation context, to properly estimate runway capacity there is a need for a suitable *runway capacity* definition; however, despite this necessity there is no uniformly used

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definition for airport and runway capacity in the literature. Such a definition should be complete and comprehensive, so we try to present one while looking at some previously presented definitions.

Capacity refers to the productive capability of a facility, Adam and Ebert (1989). Heizer and Render (2002) define *design capacity* as the maximum theoretical output of a system under ideal conditions, and *effective capacity* as the capacity expected to achieve given product mix, methods of scheduling, maintenance and standards of quality (i.e. given current operating constraints).

In Civil Aviation, runway capacity is sometimes considered as a constant rate as the reciprocal of the minimum-allowed time spacing between aircraft (e.g. Bell, 1949). An estimate obtained in this way is not practically useful since it ignores the separation variability, and unrealistically assumes *all* aircraft spacing are possibly maintainable strictly at the minimum allowed level. Newell's (1979, p 209) definition is a relatively complete one: "A capacity is defined as a maximum average flow that a facility can accommodate over a time period long enough to include a large count (say 100 or more) and which could, in principle, be sustained for an infinitely long time (if one had an arbitrarily large reservoir of aircraft)."

Hockaday and Kanafani (1974) highlight two capacity definitions in which the roles of sustainability and safety notions are not clarified: *ultimate capacity* as "the maximum number of aircraft that can be handled by a facility during a specified time period under conditions of continuous demand", and *practical capacity*as "the number of aircraft operations that can be handled by a facility during a specified period of time such that the average delay to all processed aircraft equals a certain specified amount".

De Neufville and Odoni (2003) provided a review of four definitions for the runway system capacity as follows:

- "*Maximum throughput capacity* (or saturation capacity): the expected number of movements that can be performed in one hour on a runway system without violating ATM rules, assuming continuous aircraft demand.
- "The *practical hourly capacity* (PHCAP) is defined (by the FAA in the early 1960s) as the expected number of movements that can be performed in one hour on a runway system with an average delay per movement of 4 min". We note that in this definition, delay is considered as a quality factor, and the 4 min threshold seems to be a conventional quality standard.
- "The *sustained capacity* is the measure defined, rather ambiguously, as the number of movements per hour that can be reasonably sustained over a period of several hours. 'Reasonably sustained' refers primarily to the workload of the ATM system and of the air traffic controllers.
- "The *declared capacity* is defined as the number of aircraft movements per hour that an airport can accommodate at a reasonable level-of-service (LOS)."

2.1. A revised definition

We suggest that a more comprehensive and productive definition can be as follows: *capacity* of a production (goods or services) facility is the maximum throughput (output volume in a given time) on average which can be sustained while every product satisfies some given quality characteristics that the product is meant to possess. So we note that, *capacity* and *throughput* are not equivalent terms as they might be widely confused and equivalently used in Aviation studies.

Looking into service quality factors, we believe that *safety* is an essential quality factor for runway landing or takeoff operations. So it is suitable to explicitly include thesafety term in Aviation *capacity* definition. Thus we can present our revised runway *capacity definition* as follows: *runway capacity* is the *maximum* (*landing or takeoff*) *throughput on average in a given period of time which could be safely sustained* (for an infinitely long time if we have a large pool of aircraftcontinuously coming to land or takeoff). For differentiating this definition from other types of defined capacities, one may call this one as the *true capacity*, for example.

2.2. Fleet mix issue

Fleet mix influences the runway landing and take-off capacities mainly due to wake-vortex and other safety matters so we need to be more specific in this regard. As we discuss the maximum throughput on average, we may consider the fleet mix which maximizes the number of passengers that can be handled on average. To this end, it is necessary to consider all possible fleet mix which can be handled by the runway (e.g., not all runways can serve A380) and chose the maximum one, on average.

There also can be another approach: to specifically indicate runway's capacity for a given fleet mix, e.g. all Medium (Large) aircraft in the fleet. Or to make a conventional standard about the fleet mix based upon which any runway's true capacity must be measured, e.g. all medium/large aircraft mix, or all heavy aircraft mix, etc.

2.3. Delay issue

Although we acknowledge that delay is an important measure of quality of service in serving aircraft and passengers, we do not suggest including the delay issue in the capacity definition as the delay can be controlled by practical and effective scheduling. In scheduling, the inherent separation variability must be taken into account to control delay, and this variability can cause some delay in congested periods. Delay does not influence the capacity, but the two factors of the capacity value and demand dictate the delay quantity. For a simplified illustration of the matter, consider a bottle having a capacity of V units. If there is $(V + X)$ units of liquid to be bottled, X units would not be satisfied/bottled. Now, clearly the non-bottled (or the unsatisfied volume) does not influence the bottle's capacity V. Quantity of the capacity is an input for scheduling task, and the system can be so scheduled to almost eliminate the delay by considering the capacity as a constraint.

Newell's definition as well as the *sustained capacity* of De Neufville and Odoniseem to be considering safety notion implicitly; however, it is preferable to include the *safety* term for completeness and to avoid confusion in interpretations, besides other reasons mentioned earlier. In Newell's and our definition take into account the inherent uncertainty in the realized aircraft separation (due to uncertainties in separation control around a target or desired value). One may consider a probability distribution function for the separation, the mean of which is meant to be adjusted to obtain a maximum average throughput, Jeddi, *et al.* (2006).

Differentiating between design and effective capacities (Heizer and Render, 2002),as mentioned above, is also very useful; however, the uncertainty and safety aspects must be considered in both of them. It seems that their *effective capacity* and Hockaday and Kanafani's (1974) *ultimate capacity* definitionsare close to ours.

A throughput less than the maximum average sustainable level (i.e. less than the capacity) is not maximum, and any rate higher than that (which may occur by chance due to inherent separation variability) cannot be sustained and may have an out of control risk, or otherwise, be economically wasteful (e.g. when go-around is applied to avoid the risk; Jeddi and Shortle,2007). These notions of sustainability and safety are generally missing in the runway capacity literature.

Hockaday and Chatziioanou (1986) pointed out that "there is a reluctance to accept the notion that air traffic control system safety is not absolute, and that some risk is involved." As well, there might be some reluctance in Civil Aviation community to include the safety term in capacity definition. However, we believe that safety shall not be assumed but to be insisted in the definition to generate further awareness about the presence of risks, and so motivate innovating remedies to further reduce and overcome them, whenever possible.

In describing a capacity, wealso must specify a variety of additional conditions in order that the capacity to be uniquely specified (Newell, 1979). Some important factors in this regard are the meteorological conditions, the utilized technology (aircraft physical capability, communication, navigation, surveillance, etc technologies), and the runway design (exit geometry, etc). Thus, the *effective* and *true capacities* under visual meteorological conditions (VMC) might be different than that of instrument meteorological conditions (IMC) because the weather affects the physics of the flight, the approach procedures, and the use of associated instruments. Under IMC the instrument landing system (ILS) is used, although ILS can also be used under VMC. We conclude that defining runway *capacity* as *maximum throughput* (widely used in the literature) is not complete sois not a scientifically suitable definition to follow in system design, planning and control.

REFERENCES

[1] AdamE., Ebert R.(1989) *Production and Operations Management*, Prentice Hall

[2] Bell G.E., (1949), Operational research into air traffic control. *Journal of Royal Aeronautical Society* 53; 965-976.

[3] De Neufville R., Odoni A.(2003),Airport Systems Planning, Design and Management;*McGraw Hill Companies Inc.*

[4] HeizerJ.H., RenderB. (2002),Operations Management; *Prentice Hall*.

[5] Hockaday S.L.M., Chatziioanou A. (1986), An analytical method for aircraft collision risk estimation; *Transportation Research Part B* 20B(5); 415-428.

[6] Hockaday S.L.M., Kanafani A.K.(1974), Developments in airport capacity analysis;*TransportationResearch* 8; 171-180

[7] Jeddi B.G., Donohue G.L., Shortle J.F. (2009), A statistical analysis of aircraft landing process;*Journal of Industrial and Systems Engineering* 3(3); 152-169.

[8] Jeddi B.G.,Shortle J.F.(2007),Throughput, Risk and Economic Optimality of Runway Landing Operations;*7th Air Traffic Management R&D Seminar, Barcelona, Spain.*

[9] Jeddi B.G., Shortle J.F., Sherry L.(2006), Statistical separation standards for the aircraft–approach process*; 25th Digital Avionics System Conference (DASC), Portland, Oregon, USA*; pp. 2A1-1 to 2A1-13.

[10] Newell G.F. (1979), Airport capacity and delays;*Transportation Science* 13(3); 201-241.

[11] ACI, Airports Console International, Annual Traffic data, www.aci.aero/cda/aci_common/display/main/aci_content07_c.jsp?zn=aci&cp=1-5-54_666_2__; 2010.