Assessment of intermodal freight terminals with Key Performance Indicators integrated in the BIM process

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Abstract. This paper aims at establishing a methodology to design an alternative appraisal of multimodal freight terminals taking the most of the BIM tool and its capacity for providing multi-dimensional models. The dimensional models are to be combined with different simulations models resulting in an aggregated decision-making tool to be used during the project-planning phase and thorough its life cycle. In such context, some performance measures and metrics are required, in order to identify the key factors accountable in the design and location decision process, while considering the future evolution of the terminals. Thus, the goal is to establish a set of Key Performance Indicators (KPIs) for the assessment of intermodal freight terminals in an ICT environment. The study started with a state of the art review of current performance measures used in transport, logistics and the supply chain. The findings were supported with a consultation on relevant stakeholders, in which experienced consultants in logistics, building management and design, railway operators, terminal operators and public bodies identified additional KPIs according to their particular objectives.

1 Introduction and motivation

The INTERMODEL project aims at building a tool to plan intermodal terminals, taking the most of the BIM (Building Information Methodology) software combined with simulations models of both the operations of the terminal and its adjacent transport network.

To support the decision on the best suitable design, it was necessary to provide a set of performance indicators or PI to support the decision of the most suitable option between different design alternatives.

This paper introduces the desk work done previously to the selection of PIs to be integrated in the BIM-simulation tool, since no previous work with a similar scope was found in the literature. First a state of the art on Key Performance Indicators (KPIs) is provided and discussed. Afterwards a methodology to define the list of indicators is set up and, ultimately applied to construct the framework of indicators to be calculated in further stages of the project. The communication ends with some conclusions and further steps to be followed in the near future prior the application of the selected indicators.

2 Literature review

2.1 Purpose and definition

Performance management systems are being used to ensure that companies and processes are going in the right direction, achieving targets in terms of organizational goals and objectives [1]. Key performance indicators (KPI) are widely used to measure performance as physical values able to compare, manage, report and improve performance [2], [3].

The specific set of performance indicators should vary depending on the nature of the business analysed, and as a consequence, several perspectives or typologies can be found [4], [5]. In any case, it is commonly accepted, that KPIs should be SMART (specific, measurable, attainable, realistic and time sensitive) [6] but also easily and quickly available, interpretable and with a isolatable impact [7], with a direct relevance to the objectives, and measured at an appropriate temporal and spatial scale [8].

2.2 Classification of indicators

Indicators have been consistently divided between two main groups: financial/cost/value based indicators (returns on investment, cash flow, expenditures, profit, margins, etc) and function/operational based indicators [9]–[11].

There are variations on how to structure the non-cost related indicators. Usually the parameters being valued include quality, time, reliability, flexibility, resource utilization, and so on [9], [12]–[14] but usually classified as cost, time, flexibility and quality related. Additionally customer satisfaction, safety and environmental/social performance are included [15]

To summarize, the possible classifications of indicators could be [3], [9]–[22].

To summarize the possible classification sets of indicators as found in the literature are:

- Financial-cost based /Non-financial
- Qualitative/Quantitative
- Short/Medium/Long term
- Strategic/tactical/operational level
- Function-based/Value-based
- Input/output/outcome indicators
- Time/Quality/Flexibility/reliability
- Safety and security
- Environmental and sustainable indicators
- User: management/customer/employee/society
- Transport/warehousing/customer service
- Carriers/3PL/Warehouses
- Operational/tactical/strategic

2.3 Indicators to assess intermodal terminals performance

Considering the major trend found in the literature, it has been considered appropriate to analyse indicators in this section distinguishing between operational (Table 1) and financial performance (Table 2) measures and, on the other hand, indicators related to quality service, environmental and sustainable measures (Table 3).

Specifically oriented to port terminals, the studies by UNCTAD, Owino and Trujillo [23]–[25] set a good baseline of indicators complemented by some time-related indicators found in later research [26]–[30].

Time-related indicators should help to illustrate the capability of terminals to serve customers at a certain quality level, being average turnaround time and dwell time the most commonly used despite not being reported by ports regularly [31]. In turn, turnaround time can be disaggregated in several components to be assessed separately [32], [33]. Besides the customer related indicators, labour and equipment productivity related indicators are arguably the most useful to assess a terminal's performance [34].

Strictly referring to financial appraisal, a terminal should be evaluated from the standpoint of technical efficiency, comparing its actual throughput with technically efficient optimum. Talley [27], [35] provides 17 specific PIs in this line.

Table 1. Major references for operational indicators in intermodal freight terminals.

Subcategory	PI	Main sources
Productivity/ utilization	Quay productivity/use Terminal area productivity/use Storage area use Equipment productivity/use Gate utilization Berth occupancy Labor productivity/use	[24], [28], [34]–[37]
Time-related	Turnaround time Waiting time Service time Maneuvering time Berthing time Idle time Cut-off time Dwell time Total time delays Time for administrative procedures	[24], [26], [31]–[33], [36]–[41]

Table 2. Major references for financial indicators in intermodal freight terminals.

Subcategory	PI	Main sources
Investment and funding	Infrastructure construction Equipment purchase Profitability Turnover Revenues/Expenditures	[24], [26], [27], [34]
Costs and pricing	Labour costs Equipment costs Infrastructure costs Maintenance costs	[24], [27], [34], [37]

Quality in intermodal terminals is usually understood together with time variables: waiting over service time [24], [42], [43], resource occupancy rates and total turnaround time, considering both average values and their standard deviation [44]–[47]. Some additional service (quality) indicators include: reliability, flexibility and resilience, accessibility, safe and security [47]–[49].

On the other hand, energy efficiency and emissions performance indicators are gaining momentum over the recent years with some models to quantify them [50]–[53]. Environmental indicators range from air emissions to noise hindrance, habitat loss, energy recovery and recycling capacity [54]–[56]. An interesting subset of papers list environmental PIs for the placement of dry ports [57]–[59], considering environmental protection, reduction of air emissions or even promotion of intermodal transport through the modal shift.

Finally, socioeconomic PIs can include gross value added, new employment measured in full-time equivalent, fiscal revenues, attracted trade values or their relative forms [10], [50], [60].

Table 3. Major references for quality service indicators in intermodal freight terminals.

Categories	PI	Main sources
QUALITY: Safety and security Flexibility Reliability and service care Accessibility and connectivity	Time-related % of loses or damage Delays/wrong delivery Employees qualification Train/vessel delay in departure (%) Schedule reliability	[19], [43]–[46], [48], [61]–[63]
ENVIRONMENT Accidents Noise Air pollution Climate change Water pollution Habitat loss Hydrologic impact Energy consumption Sprawl Congestion Resource efficiency	Number of transport accidents, fatalities, injured, polluting accidents, etc. Crash casualties cost Air pollution emission Embodied emission Noise pollution Impervious surface coverage Habitat preservation Community livability Water pollution Use of renewal fuels Energy efficiency Vibrations Mode split	[19], [52], [53], [59], [64]
SOCIO-ECONOMIC: Economic impact Return on investment	Value added per ton Employment per unit of land Value added per publicly invested euro Terminal value added	[10], [31], [50], [60]

2.4 Performance indicators within the BIM concept

The only links found in the literature between BIM development and performance measures are mainly focused on the benefits of using BIM in construction projects [65]–[67]. In particular, this kind of indicators try to measure the effectiveness of BIM as a tool in project management. The only KPI currently integrated in BIM is the cost estimation at any point of the design phase, which can be used as input data to evaluate financial indicators.

3 Methodology and results

First, an identification of the stakeholders, their strategy and mission and their perspectives in the performance system and specific goals was done.

In a second stage effectiveness criteria and feasibility of each indicator is set resulting in a comparative scoreboard to be used to assess different terminal layouts, operational processes, allocation, equipment, materials, etc. as seen in Figure 1.

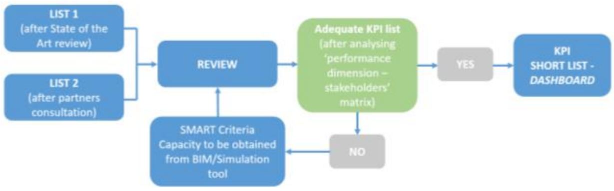

Figure 1. KPI & PI list methodology.

In parallel to the literature review, main partners involved in the industry of intermodal transportation (terminal operators, public administration, road freight providers, railway operators and experts in transport and logistics) were consulted to provide their inputs and experiences regarding the use of performance measures in their daily decisions.

3.1. Strategies and goals / actors involved

For the particular case of intermodal freight terminals, future and current working intermodal facilities should focus on:

- Optimising the economic performance.
- Ensuring the service quality.
- Minimizing the effects of the hub on the immediate surroundings.
- Reducing the environmental impact and external costs.
- Increasing the benefits, in terms of social impact.

3.2 Actors involved

Different actors are involved, each having its own business strategy and relevant indicators (table 4):

Table 4. Relevant actors and functions in freight terminals.

Actors	Hinterland / Rail network	Terminal
Public authorities		
Planning agency	*Modal shift* *Economic development of the metropolitan*	

Actors	Hinterland / Rail network	Terminal
	area	
Port authority	*Modal shift* *Port throughput*	
Operators		
Rail operators *Haulage companies*	*Volumes* *Door-to-door transport*	
Shipping lines	*Haulage* *Container logistics*	*Buffer*
Terminal operators (rail, road)		*Management* *Intermodal* *Storage*
Freight forwarders	*Haulage*	*Consolidation* *Deconsolidation* *Buffer* *Cargo added value*
Investors		
Private companies *Investment organizations*		*Success in terms of financial results* *Operating profitability*

3.3 Selection of effectiveness criteria and feasible KPIs and PIs set

Considering the methodological setup and the strategic goals, performance dimensions and stakeholders a framework of main stakeholders and relevant categories is constructed (Table 5).

Table 5. Indicator's categories proposed for the KPIs and PIs set.

	Investor	Operator	Public authority
Operation	*Productivity*	*Efficiency* *Productivity* *Volume* *Congestion*	
Finance	*ROI* *Costs* *Revenues*	*Unit cost* *Maintenance costs* *Revenues*	*Employment* *Maintenance costs* *Investment on modal shift*
Quality		*Service quality – time* *Damages*	*Congestion (road and rail)*
Environment		*Energy efficiency* *Alternative fuels*	*Carbon footprint*
Safety			*Accident costs*

Once the main categories are identified (items introduced in matrix cells), particular performance indicators are proposed (Table 6) for each category regarding existing intermodal terminal operations and three different scopes: intermodal terminal, hinterland, and railway network.

Table 6. Classification of performance indicators (KPIs and PIs).

Key Performance Indicators (KPIs)	Performance Indicators (PIs)
Operational	
1. Intermodal terminal throughput (volume) 2. Equipment utilization 3. Gate utilization 4. Labour utilization rate 5. Storage area utilization 6. Rail track utilization 7. Berth utilization 8. Turnaround time 9. Waiting time	28. Maneuvering time 29. Service time 30. Berthing time 31. Idle time (equipment)
Financial	
10. Return On Investment (ROI) 11. Terminal's profitability 12. Operating efficiency (operating margin) 13. Operating revenues per unit 14. Operating benefits per unit 15. Direct jobs sustained by terminal activities 16. Indirect jobs sustained by terminal activities 17. Road and rail track maintenance cost	32. Capital Expenditure (CAPEX) 33. Operational Expenditure (OPEX) 34. Corrective maintenance cost – equipment 35. Preventive maintenance cost – equipment 36. Corrective concrete structures maintenance cost 37. Preventive concrete structures maintenance cost
Quality, environmental and safety	
18. Easiness of entry and exit from highways 19. Easiness of entry and exit from rail network 20. Energy consumption per handled unit 21. Carbon footprint per unit 22. Delays produced (reliability) – road 23. Delays produced (reliability) - railway 24. CO, NOX, SOC, PM emissions 25. Population exposed to high levels of traffic noise 26. Number of road accidents 27. Number of railway accidents	38. Waiting time / turnaround time 39. Use of alternative fuels from total consumption 40. Accidents related to hazard cargo

Therefore, each proposed performance indicator is related to a: i) performance dimension; ii) stakeholder; iii) category; iv) scope and; v) strategic goal.

Since some performance indicators are dependent on others, it is convenient to classify the proposed indicators in two levels:

- High-level performance indicators (KPIs), focused on big picture performance goals.
- Secondary level performance indicators (PIs), focused more on daily processes in each area of an intermodal freight terminal (e.g. cargo handling, container handling, shunting, shipping, etc.).

4 Conclusions

A selected group of performance indicators to be integrated in BIM-simulation tools to design intermodal freight terminals (road/rail and road/rail/sea facilities) is given with a holistic approach.

These indicators evaluate (1) the performance of terminal operations from both technical and economical point of view; (2) the external effects as regards to sustainable, safety and environmental terms; and (3) the financial requirements from the investor/management point of view.

The literature review showed that operational and financial performance indicators are vastly employed for seaport and intermodal terminals but quality service, sustainable and environmental measures are particularly required for evaluating freight terminals (transshipment nodes within supply chains) and its impact on its neighborhood.

The integration of selected performance indicators in BIM tools for assessing the performance of intermodal freight terminals in both construction and operating phases will constitute a great contribute since just construction cost indicators are currently integrated in BIM.

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